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The Effects of Polyphenol Supplementation on Muscular Strength, Power, and Soreness Following Eccentric Exercise

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The Effects of Polyphenol Supplementation on Muscular Strength, Power, and Soreness Following Eccentric Exercise

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ABSTRACT

The Effects of Polyphenol Supplementation on Muscular Strength, Power, and Soreness Following Eccentric Exercise

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An acute bout of unaccustomed eccentric exercise causes prolonged strength loss and delayed onset muscle soreness (DOMS) for several days. Chronic dietary supplementation with polyphenols, from pomegranates, has been shown to accelerate recovery following eccentric exercise, but the optimal dose is unknown. The purpose of this study was to determine the effect of dietary supplementation with different doses of pomegranate juice concentrate (PJC) on muscular strength, power, and soreness throughout a 96-hour time period following an acute bout of eccentric exercise. Healthy recreationally active males (n=45) were assigned to one of three treatment groups: Once-daily PJC (1x), twice-daily PJC (2x), or placebo (PLA) supplementation over a period of eight days. A 1x dose of PJC provided approximately 650 mg GAE. On day four of each treatment, subjects performed downhill running intervals (-10% grade) over a 40-minute period followed by 40 repetitions of eccentric elbow flexion at 100% of concentric 1-RM. Muscle soreness of arms and legs, maximal isometric strength of the elbow flexors (EF) and knee extensors (KE), vertical jump height (VJ_{height}) maximal cycling power (P_{max}), and 10-meter sprint velocity (V_{10m}) were assessed pre-exercise and 2, 24, 48, 72, 96 hours post-exercise. Additionally, maximal instantaneous power (IP_{max}), maximal velocity (V_{max}), maximal torque (T_{max}), and torque at 0° (T_0) were assessed on the inertial load power cycle pre-exercise and 24, 48, 72, 96 hours post-exercise. Throughout the 96-hours post-exercise, isometric EF strength was significantly higher in 1x and 2x groups as compared to PLA (main treatment effect, 83.6 ± 2.7% vs. 85.6 ± 1.9% vs. 78.4 ± 1.8%, respectively; $p < 0.001$). Isometric KE strength was significantly higher in 1x and 2x groups as compared to PLA (main treatment effect, 93.9 ± 1.5% vs. 91.6 ± 1.5% vs. 87.1 ± 1.8%, respectively; $p < 0.001$). Both VJ and V_{10m} were significantly higher in 1x compared to PLA (main treatment effect, 99.9 ± 0.9% vs. 98.0 ± 1.0%, respectively, $p = 0.037$; 100.0 ± 0.8% vs. 97.8 ± 0.7%, respectively, $p = 0.003$). Muscle soreness and P_{max}, were similar at all time points between groups. We conclude that dietary supplementation with 1x or 2x PJC results in higher isometric strength values compared to placebo for EF and KE muscles during the 96-hour period after an acute bout of eccentric exercise.

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INTRODUCTION

When an individual performs a bout of exercise, specifically eccentric biased exercise, it may result in muscle damage that causes a prolonged strength loss that will negatively affect athletic performance [1]. Amidst strength loss, other notable symptoms of eccentric induced muscle damage are decreases in range of motion, as well as, swelling and delayed soreness of the muscle exercised [2]. This condition following eccentric exercise is called delayed onset muscle soreness (DOMS). In the days following exercise, DOMS occurs in individuals who are not accustomed to performing exercise with a heavy eccentric component. Symptoms of DOMS peak 24-48 hours following exercise [3]. After 24-48 hours recovery of strength and soreness begin to return to baseline values, however this may take 1-2 weeks, and in rare cases up to four weeks [4].

It is believed that during a single eccentric contraction, damage occurs due to overstretching or “popping” of weaker sarcomeres. As the muscle fibers enter a region of instability in the length-tension curve, there is greater stretch on individual sarcomeres. Stronger sarcomeres contract and are able to resist this stretch, while weaker sarcomeres cannot and are forced to relax. Relaxation of weaker sarcomeres causes them become overstretched. One individual eccentric contraction causes minimal damage, however as a higher volume of eccentric contractions is performed, the greater the amount of overstretching occurs. Widespread areas of overstretched sarcomeres cause structural disruption of the muscle fiber resulting in damage to the tissue [5-8]. Damage to the muscle fiber allows for increased accumulation of intracellular calcium. This alteration in the muscle fibers ability to maintain normal calcium homeostasis results in reduced maximal calcium activated force, reduced titanic calcium, reduced calcium sensitivity, elevated resting calcium, and most notably excitation contraction (EC) coupling failure [9]. All of these factors result in the severe decrease in strength that is immediately associated with eccentric exercise.

In the hours and days following the initial injury to the muscle fiber, a secondary injury occurs that is caused by the summation of oxidative stress [10-12], inflammation [13-19]. Phagocytosis of necrotic tissue is a necessary task, however it may be detrimental, as the release of reactive oxygen species (ROS) may damage more tissue. If these signaling cascades can be attenuated by either a reduction of oxidative stress and/or inflammation, the extent of secondary damage may be lessened and recovery from eccentric exercise may be accelerated.

Dietary supplementation with polyphenols has been effective in improving recovery following eccentric exercise [20-30]. The pomegranate fruit, which contains a high concentration of polyphenols, has many anti-inflammatory and anti-oxidative properties[31]. Previous studies have demonstrated a positive effect in both trained and untrained individuals supplementing with 1300 Gallic Acid Equivalents (GAE) per day of pomegranate fruit extract prior to and following eccentric exercise [29, 30]. No study has been completed to demonstrate if a dose response exists with dietary supplementation of pomegranate polyphenols. Also, no study has been completed testing if the rate of recovery following downhill running would be improved when supplementing the diet with pomegranate polyphenols. We intend to study the effects of differing doses of dietary supplementation of pomegranate juice concentrate (PJC) on recovery of strength and power following a bout of downhill running and eccentric contractions of the elbow flexors.

REVIEW OF LITERATURE

ECCENTRIC EXERCISE

An eccentric exercise can be described as any exercise in which the muscle resists lengthening. During an eccentric contraction the elongation of the muscle occurs while tension is maintained in an effort to decelerate the opposing force. When an individual performs unaccustomed eccentric exercise muscle damage occurs, a demonstrated by prolonged strength loss and muscle soreness. Modes of exercise that result in this type of damage are eccentric contractions of isolated muscle groups (i.e. elbow flexors, knee extensors, etc.) [1, 8, 10, 13, 16, 17, 21, 27, 32-44] and downhill running [18, 19, 45-57]. Both exercise types are well studied and effective, repeatable methods to elicit eccentric exercise induced muscle damage.

Eccentric contractions are able to produce greater force than isometric or concentric contractions, but the effect they have on the muscle is somewhat deceptive [58]. Fatigue during concentric contractions is due to metabolic fatigue and is distinguishable by the burning feeling in exercising muscles. This is not the case when performing eccentric exercise [3]. Eccentric exercise is not nearly as metabolically stressful as concentric exercise, however during high force eccentric exercise there is damage to the muscles that performed the exercise [40, 59]. This type of damage does not occur during concentric exercise, however it does contribute to fatigue, as the force generating capacity of the muscle is diminished due to loss in structural integrity of the muscle. An individual who has performed eccentric exercise may not feel as though they have worked hard, however strength loss is similar to that following concentric contractions of the same muscle group [40].

Although during eccentric exercise, the force of muscle contraction can be greater than during isometric or concentric exercise [60], muscle damage can occur even at submaximal intensities assuming the volume is high enough. This is demonstrated during downhill running. Downhill running requires lower oxygen consumption than uphill or flat level running [49, 56], soreness occurs almost exclusively following downhill running, aside from running of extreme distances (i.e. marathon) [20, 23]. Methods of assessing muscle damage for downhill running are similar to markers seen following maximal eccentric contractions, however time course and magnitude differ [4].

Difference in time course and magnitude of damage may be due to force of contractions being lessened in downhill running, the muscle damage achieved during maximal eccentric contractions is isolated to single muscles (i.e. elbow flexors: biceps brachii and brachialis muscles or in the case of knee extensors: quadricep muscles) as opposed to downhill running which requires a large range of muscles of the lower body (i.e. quadricep, hamstring, glute, and lower leg plantar flexor muscles).

Individuals performing downhill running to elicit muscle damage typically run at decline of 5-15%, speed corresponding to 60-80% of estimated VO2 peak velocity attained on a flat surface, and for duration of 20-60 minutes. Maximal isometric strength of the knee extensors is a primary method used to measure decreases in force output following downhill running [18, 47, 48, 50, 51]. Typically, the initial decrease in isometric strength from downhill running is between 10-25% of pre-exercise values and increase linearly until complete recovery at 5-7 days post-exercise [47, 48]. Aside from decreased maximal isometric strength, both running economy [45, 47, 48] and glucose tolerance [52] are negatively affected following downhill running.

Another mode of exercise that can be performed to induce eccentric damage is by having an individual perform eccentric contractions with an isolated muscle group. Typically, muscles of the elbow flexors or knee extensors are used for this type of study design. An individual may complete eccentric contractions isotonically or isokinetically. Isokinetic eccentric contractions allow the researchers to quantify work completed, however a limitation of this device is that the individual must resist maximally, which is somewhat subjective, as the individual can "fake it". Isotonic eccentric contractions allow the individual to perform eccentric contractions using a weight, usually a certain percentage of their 1-RM [30]. Strength loss for maximal isometric strength following eccentric contractions of a single muscle or muscle group typically range from 30-60% lower than maximal values. A greater decrease may be due to the fact that greater force of contractions are usually associated with this type of eccentric exercise and/or the isometric strength testing is performed using the same movement and thus same muscles used to perform eccentric exercise. This may give a more specific indicator of muscle damage sustained, unlike when testing isometric strength following downhill running, as downhill running affects a wider range of muscles impossible to test simultaneously.

DELAYED ONSET MUSCLE SORENESS

Exercise induced muscle damage occurs primarily, but not exclusively, during exercise that is both unaccustomed to the individual and contains high volume or force eccentric contractions [40, 59]. Exercise of this type includes repeated eccentric contractions of the elbow flexors or knee extensors [1] and downhill running [57]. Immediately following exercise, strength is reduced. This strength loss is similar to what is observed following concentric contractions [40]. However, unlike strength recovery following concentric contractions, which takes 1-2 hours, strength recovery after eccentric exercise is negligible during that time period [4]. Amidst prolonged strength loss, the muscle group that performed eccentric exercise may demonstrate a reduced range of motion and slight muscular soreness and swelling, as well. In the days following eccentric exercise, muscle damage increases [61], strength remains attenuated, and swelling may develop in the body part exercised [53]. However, the most notable consequence occurs in the days following novel eccentric exercise.

Although an individual may be slightly sore in the hours following eccentric exercise, soreness tends to drastically peak 24-48 hours post-exercise [3]. This delayed occurrence of soreness is Delayed Onset Muscle Soreness (DOMS). While DOMS typically subsides within one week., strength loss and swelling may linger for up to one month following a bout of unaccustomed eccentric exercise [4]. Because the exact causative mechanisms that cause DOMS are still relatively unknown, this review will briefly describe hypothetical events leading to this condition and therapeutic remedies that have been aimed at speeding recovery.

The first scientific publishing that recognized a DOMS-like effect of soreness was by Theodore Hough at the turn of the 20th century Hough stated that "when an untrained muscle makes a series of contractions against a strong spring, a soreness frequently results which cannot be regarded as a phenomenon of pure fatigue [62]." Although this recognition of DOMS was observed as a confounding variable in that study, the following year Hough published a study delving into possible mechanisms and modes of exercise that cause this atypical soreness. In the follow up study the soreness was simply referred to as "the second kind of soreness." Hough postulated this soreness was caused by "some sort of rupture within the muscle" that occurred only in untrained muscle. Although relatively correct, he was unable to determine mechanisms that cause delayed soreness, as some study participants developed DOMS, while other did not. Therefore he suggested that in future studies any subjects that reported "the second kind of soreness", simply be discarded [63]. These studies by Hough were the first to identify what would later be referred to as DOMS, however the mechanisms causing it lay unknown and relatively unstudied for over half a century.

INITIAL INJURY

It was in the 1950's it was well known that eccentric contractions produced more force and required less energy than either isometric or concentric contractions [58]. However, it was in 1956, that Erling Asmussen who discovered that performing eccentric contractions is what causes DOMS [2]. Prior to and following this finding, many theories existed on what occurs within the muscle during and/or following eccentric contractions that cause DOMS. It was in 1981 that Friden and colleagues shed some light on this topic by taking muscle biopsies prior to and 48 hours following eccentric exercise. Biopsies taken prior to exercise displayed normal muscle fiber arrangement, however biopsies taken 48 hours after exercise displayed damage as evidenced by disruption and disorganization of sarcomeres [61]. The damage to the muscle fibers seemed to originate from the Z-band, indicating the eccentric exercise may induce damage due to a structural weakness in the Z-discs. This study was the first to show extensive damage to the muscle after eccentric exercise, however, since no muscle biopsies were taken immediately after exercise the exact cause of DOMS could not be determined.

Newham and colleagues analyzed biopsies taken from the vastus lateralis of either concentrically or eccentrically exercised legs. Biopsies were taken prior to, immediately after and 24-48 hours after performing 20 minutes of bench stepping exercise. Subjects used one leg to step up concentrically and the other to step down eccentrically, thereby following exercise one leg had only exercised concentrically and the opposite leg had only exercised eccentrically. Immediately following and 24-48 hours after exercise, negligible damage was present in the leg that performed exercise concentrically. However, in the leg that had performed eccentric contractions, damage was present immediately after exercise similar to that seen by Friden and colleagues. It was also observed that damage present in muscle biopsies taken 24-48 hours after exercise was greater in magnitude than damage assessed immediately following exercise [59]. Thus, it was implied that at some point during the 24-48 period of time following eccentric exercise the muscle was damaged further. Another notable finding in this study was that concentric exercise does not lead to DOMS, as no damage was sustained during or after exercise.

The results of these studies on exercise induced muscle damage led to many theories on what exactly happens during and after eccentric exercise to cause damage and

DOMS. The predominately accepted theory is that initial damage occurred is due to the overstretching or “popping” of weaker sarcomeres. During an eccentric contraction, as the muscle fibers enter a region of instability in the length-tension curve, there is greater stretch on individual sarcomeres. Stronger sarcomeres contract to resist this stretch, while weaker sarcomeres cannot. As weaker sarcomeres relax, they become overstretched. One individual eccentric contraction may cause this overstretching of weaker sarcomeres, causing minimal damage, however as more eccentric contractions are performed, more sarcomeres become overstretched. Widespread areas of overstretched sarcomeres causes massive disruption of the muscle fiber structure and results in damage to the muscle fibers [5-8]. The acceptance of this theory is not without its doubters, as the cause of initial strength loss is still undetermined as there are other effects of eccentric exercise that occur that are able to partially explain strength loss.

Increased accumulation of intracellular calcium occurs after eccentric exercise and affects excitation contraction (EC) coupling; causing significant strength loss [9]. This alteration in the muscle’s fibers ability to maintain normal calcium homeostasis results in reduced maximal calcium activated force, reduced tetanic calcium, reduced calcium sensitivity and raised resting calcium [9]. Although this alteration in calcium homeostasis may be caused by disruption and damage to the muscle fibers, it has been shown that when eccentrically contracted muscle is exposed to caffeine, most of the force decrement is abolished [9, 64]. This indicates that alterations in calcium homeostasis do affect strength loss after exercise. This also indicates that, although the eccentrically contracted muscle is damaged, damage is not what plays a major part in initial strength loss. If damage and disorganization played a major part in strength loss, it would not be able to be recovered by caffeine exposure. Thus, there is a strong argument for the case of EC coupling failure via altered calcium homeostasis as the factor contributing most to post-exercise decrease in strength, although arguments continue for proponents of both theories. The exact mechanism causing the initial decrease in strength following eccentric exercise is still unknown and most likely impossible to find out, but it is nearly indisputable that the initial strength loss is resultant from either damage and/or EC coupling failure of the muscle.

SECONDARY INJURY

In the hours and days following the initial injury to the muscle fiber a secondary injury takes occurs. Immediately following exercise, whether eccentrically or concentrically biased, muscle begins to recover. However, it has been shown that 6-12 hours following unaccustomed eccentric exercise, a secondary injury occurs resulting in an additional drop in strength and more muscle damage [13, 38]. The secondary injury that occurs is caused by the summation of oxidative stress [10-12], inflammation [13-19] and possibly by activation of intracellular calcium dependent proteases [44, 65] at the site of the initial injury. Immediately following exercise, an initial wave of white blood cells, consistent of neutrophils and macrophages, accumulate at the site of injury, followed by a delayed wave of macrophages 24-48 hours later [13, 14, 17, 66, 67]. Although, neutrophils and macrophages are necessary for recovery from eccentric exercise induced muscle damage, as they phagocytize and regenerate the damaged tissue [14]. A potentially detrimental effect of phagocytic metabolism is the release of reactive oxygen species (ROS) that may actually damage more tissue and kill the leukocyte. It has been shown that macrophages do not contribute to muscle injury, and are generally associated with regeneration [66, 67]. However, it is neutrophils that have been shown to cause injury to muscle tissue [14, 15, 33, 39, 68]. When neutrophils are cultured with skeletal muscle myotubes, damage to the tissue increases as the concentration of neutrophils increase [68]. Study in rats has shown that when the neutrophil binding site on the endothelium is removed, neutrophil accumulation to the site of injury is prevented and isometric force is recovered faster [15]. Both of these studies indicate that neutrophils play a part in impairment of recovery from muscle damage, however this has been shown to not be true in all cases, as some data show that neutrophil infiltration is a necessity for recovery [42].

Following eccentric exercise intracellular calcium is increased in the injured muscle fibers. This activates intracellular calcium dependent proteases, “calpain” [44] and “caspases” [65].. Activated proteases may act as another method of damage to muscle following eccentric exercise. Additionally, increased ROS, as well as intracellular calcium, cause mitochondrial release of cytochrome C as another mechanism of these proteolytic proteases [69]. Mitochondrial calcium uptake itself may also result in production of ROS [10]. Regardless, excessive ROS production causes further oxidative stress and may cause greater membrane damage, increasing membrane permeability. Damage to the cell membrane results in increased signaling of inflammatory cells meant to regenerate and degrade damaged tissues, however these cells continually release ROS. Thus, results in a cycle of repetitive damage that leads to more extensive damage. If these signaling cascades can be attenuated by either a reduction of oxidative stress and/or inflammation, the extent of secondary damage may be lessened and recovery from eccentric exercise may be accelerated.

DIETARY SUPPLEMENTATION

Dietary supplementation in humans and animals with traditional anti-oxidants (vitamin C & E) [32-35, 39, 41, 70] or non-steroidal anti-inflammatory drugs (NSAIDs) [36, 37, 43] has been studied as a method aimed at reducing secondary damage following eccentric exercise. It is believed that if oxidative stress and/or inflammation can be attenuated DOMS will be mitigated. However, studies supplementing with anti-oxidants and NSAIDs have shown equivocal results, with the general consensus being that they do not improve recovery following novel eccentric exercise. In one study, supplementation with vitamin E may have actually increased damage, as observed by increased release of creatine kinase, a marker of membrane permeability associated with muscle damage [33]. NSAIDs are similarly ineffective at improving recovery following eccentric. However, some NSAIDs have been shown to decrease soreness following eccentric exercise [37], but have no effect on recovery of strength [36, 37]. Overall, researchers agree that dietary supplementation with traditional anti-oxidants and NSAIDs do not aid in recovery from eccentric exercise.

An untraditional type of dietary supplementation is polyphenol supplementation. Polyphenol supplementation has been observed to be effective in improving recovery following novel eccentric exercise [20-30]. Polyphenols are a class of phytonutrients that contain potent anti-oxidant and anti-inflammatory properties that may aid in recovery of muscle damage [31]. When injured human myotubes are exposed to the polyphenolic compound curcumin regeneration of muscle tissue occurs at a faster rate [71]. Davis and colleagues demonstrated beneficial effects of dietary curcumin supplementation *in vivo* using a mouse model of downhill running. Mice who were supplemented with curcumin had greater regeneration of muscle tissue and recovery of strength following exercise [22]. Polyphenols derived from apple peels have been supplemented in rats have also shown improved recovery following eccentric exercise, similar to that of Davis and colleagues [26].

The benefits of polyphenol supplementation *in vitro* and *in vivo* in rodents also translates to humans as an effective means to improve recovery following eccentric exercise [20, 21, 23, 25, 28-30]. Multiple studies providing tart cherry juice have were effective in decreasing muscle soreness and/or improving strength recovery following marathon running [23, 24] or high force eccentric contractions [20, 21]. Additionally, tart juice has also been shown to decrease oxidative stress following an ischemia reperfusion challenge [28], thereby demonstrating its value in suppressing ROS stress. Pomegranates supplementation improves recovery from eccentric exercise in humans [29, 30]. The pomegranate fruit itself contain a high concentration of polyphenols among polyphenolic compounds [31]. The phytonutrients that account for the majority of the polyphenols found in pomegranates are ellagitannins, punicalagins and anthocyannins. Among other commonly used polyphenol containing beverages, pomegranate juice has been shown to have the highest content of polyphenols and anti-oxidant capacity [72]. Although anti-oxidant and anti-inflammatory supplementation has yielded equivocal results on recovery from eccentric exercise, it is possible that the unique balance phytonutrients found in these polyphenol rich compounds may aid in recovery from eccentric exercise in combination.

When specifically focusing on pomegranate supplementation, Trombold and colleagues demonstrated that supplementation of 1300 mg Gallic Acid Equivalents (GAE) per day in untrained individuals accelerates isometric elbow flexor strength recovery 2-3 days following maximal eccentric contractions of the elbow flexors [29]. A follow up study in resistance trained individuals demonstrated an overall treatment effect of 1300 mg GAE/day of dietary pomegranate supplementation in recovery of isometric elbow flexor strength following maximal eccentric contractions of the elbow flexors [30]. The dose used in these studies may be greater than what is commercially available. To the best of our knowledge, no study has been conducted to investigate if a dose response effect of pomegranate polyphenols may alleviate symptoms of DOMS.

METHODS

SUBJECTS

Forty-five healthy, non-smoking, recreationally active males (age: 22.3 ± 4 years, weight: 73.8 ± 11.5 kg, height: 174.9 ± 6.2 cm) recruited from The University of Texas at Austin community participated in this study. The experimental protocol was approved by The University of Texas at Austin Institutional Review Board. All subjects provided written informed consent to participate in the experimental protocol and had no history of injury to the ankle, knee, hip, wrist, elbow, or shoulder within the last two years and were not taking part in any type of physical therapy. Subjects were disqualified if they had participated in any structured resistance training or running program of any type over the previous six months. Subjects were instructed to limit any strenuous activity throughout the experimental protocol. All anti-inflammatory and/or anti-oxidant supplements were discontinued and prohibited during the entire experimental protocol. Other criteria for inclusion were: no history of hypertension, kidney dysfunction, active weight loss > 5 kg. in the prior 3 months, angiotensin converting enzyme (ACE) inhibitor, lipid-lowering, selective serotonin reuptake inhibitor (SSRI) or anti-inflammatory steroid medication use.

DESIGN

This study was a double-blind, counter-balanced, placebo-controlled experiment with one testing period lasting eight days. Subjects were assigned to one of three supplementation groups. During the eight-day supplementation protocol, the bout of exercise used to elicit DOMS was performed on the fourth day of supplementation. Measures of recovery were made throughout the next four days. All subject performed modalities of eccentric exercise in the same order, with downhill running preceding eccentric contractions of the elbow flexors.

Soreness and performance measurements were collected on Day 4 at pre-exercise (PRE), 2 hours (2h; Day 4), 24 hours (24h; Day 5), 48 hours (48h; Day 6), 72 hours (72h; Day 7), and 96 hours post-exercise (96h; Day 8). Each subject reported to the human performance laboratory at the same time of day for all subsequent testing days. Additionally, a dietary recall was used to ensure that all subjects replicated the same diet prior to reporting to the laboratory.

SUPPLEMENTATION

Supplementation of pomegranate juice concentrate (PJC) or placebo (PLA) were consumed each morning and evening, 12 hours apart, starting on Day 1 of the experimental protocol following the final familiarization session. PJC and PLA drinks were provided by POM Wonderful Inc., LLP (Los Angeles, CA). Subjects were assigned to one of three groups: Once-daily (1x), twice-daily PJC (2x), or placebo (PLA) supplementation. During the 1x treatment, subjects supplemented with PJC in the morning and placebo in the evening.

Products were provided to subjects in 500 mL bottles. Each subject received two bottles of supplementation, labeled A.M. and P.M., to be taken in the morning and evening, respectively. Subjects were instructed to dilute one ounce of supplementation in approximately eight ounces of water. Each 16 oz. bottle of PJC contained 650 mg/oz. Gallic Acid Equivalents (GAE), while PLA contained 0 mg GAE. A one-ounce serving of both PJC and PLA contained 24 grams of carbohydrate per ounce as maltodextrin, sucralose, coloring, and flavoring.

Eccentric Exercise Protocol

Eccentric exercise consisted of downhill running intervals and bilateral isotonic eccentric contractions of the elbow flexors. On the morning of Day 4 of the experimental protocol, subjects performed the eccentric exercise bout approximately ten minutes following the pre-exercise soreness and performance measures. All subject performed downhill running prior to eccentric contractions of the elbow flexors.

Downhill Running

Downhill running consisted of 10 sets of running down the ramps of Darrell K. Royal – Texas Memorial Stadium. The ramps of the stadium contain 10 flights of ramps that are 140 feet in length and decline at a grade of -10%. All subjects started at the 10^{th} floor and ran at a similar pace, 8 mph (2 min/set), set and paced by a member of the research team until they arrived at the ground floor. Following each set, subjects took the elevator back to the 10^{th} floor to perform the subsequent set. The time taken from the end of each set to the beginning of the next was considered the rest and was approximately 2-2.5 minutes in duration per set. Total exercise time was approximately 45-50 minutes, consisting of 20 minutes of downhill running and 25-30 minutes of rest. In an attempt to ensure equal response between each legs, two sets of ramps were used in alternating fashion, as one ramp descended in a clockwise pattern and the other in a counter-clockwise pattern. Therefore, no leg would be favored or affected more by the direction of turns between flights. Throughout the downhill running protocol subjects were provided water and drank *ad libitum* during the rest periods.

ISOTONIC ECCENTRIC CONTRACTIONS

Approximately 10 minutes following the final set of downhill running, subjects began the eccentric contractions of the elbow flexors portion of the exercise protocol. Subjects performed 40 repetitions of bilateral isotonic eccentric contractions of the elbow flexors at a load equal to 100% concentric one-repetition maximum (1-RM) using an EZ curl barbell. Subjects were seated on a preacher curl apparatus with the posterior side of the upper arm flat against the cushion of preacher curl apparatus. On the subjects ready, the tester would place the barbell in the subject's hands. The tester ensured that the subject was ready to perform the eccentric contraction by asking "are you ready?" On the tester's signal, the participant was instructed to lower the barbell eccentrically with control from complete elbow flexion to complete elbow extension at the command "5,4,3,2,1,0." At "0" the subject was at complete elbow extension and maintained tension until the tester took the barbell from the subject. This was repeated for 40 repetitions, with approximately 20-30 seconds rest between each repetition. If at any point the subject was unable to maintain control of the eccentric contraction or lost muscle tension during the five-second count, a five-minute rest was given and the protocol was then continued until a total of 40 repetitions were accumulated.

Performance Measurements

Performance measurements were done in the similar postprandial state and same order for every subject preceded by measurements of local muscle soreness. Ordering of performance measurements was: (1) Isometric knee extensor (KE) strength, (2) isometric elbow flexor (EF) strength, (3) inertial load maximal cycling power (P_{max}), (4) vertical jump (VJ_{height}), and (5) 10-meter sprint velocity (V_{10m})

Isometric Knee Extensor Strength

Isometric KE strength was measured bilaterally using a modified knee extension apparatus. Each subject was strapped into the knee extension device at the waist and shoulders. Strength was recorded using a load cell (LC101-500, Omega Engineering, Stamford, CT) secured to the base of the apparatus using a galvanized steel cable and secured to the subject's lower legs by padded ankle straps. The subjects performed three trials, at 65° of knee flexion, with 120 seconds rest in between each trial. Isometric KE strength was reported as the peak value (kg) attained in each trial. This measurement was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

Isometric Elbow Flexor Strength

Isometric EF strength was measured bilaterally while seated on a modified preacher curl apparatus. Strength was recorded using a load cell (LC101-500, Omega Engineering, Stamford, CT) secured to the base of the apparatus using a galvanized steel cable and connected to a curl bar the subjects held in their hands. The subjects performed three trials, at 135° of elbow extension, with 120 seconds rest in between each trial. Isometric

EF strength was reported as the peak value (kg) attained in each trial. This measurement was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

INERTIAL LOAD MAXIMAL CYCLING POWER

P_{max}, maximal instantaneous power (IP_{max}), maximal velocity (V_{max}), maximal torque (T_{max}) and torque at 0° (T_0) were determined using an inertial load cycle ergometer as described previously [73]. This testing procedure has been proven valid, reliable, and safe through repetitive use in our laboratory. Each subject performed four maximal efforts with 60 seconds of rest provided between each trial. P_{max}, IP_{max}, V_{max}, T_{max} and T_i were determined from the average of the top two values for P_{max}. P_{max} was defined as the highest power attained averaged over one revolution, while IP_{max} was defined as the highest power attained at any degree of any revolution. T_{max} was defined as the highest torque attained averaged over one revolution, while T_0 was defined as the torque at an angular velocity of 0° per second. V_{max} was defined as the highest angular velocity attained. This measurement was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise. However, due to constraints of the software used for analysis, values for IP_{max}, V_{max}, T_{max} and T_0 were only obtained at PRE, 24, 48h, 72h, and 96h post-exercise. In some cases the average of the top two values for P_{max} wasn't available to obtain values for IP_{max}, V_{max}, T_{max} and T_0. Under these circumstances values for IP_{max}, V_{max}, T_{max} and T_0 were assessed from the highest value for P_{max}.

Vertical Jump Height

VJ_{height} was determined using a Vertec jump training apparatus (Gill Athletics, Champaign, IL). Prior to the first attempt subjects were instructed to stand directly under the Vertec blades and reach the dominant hand upward, perpendicular to the floor and parallel to the Vertec apparatus. The highest blade touched was recorded as standing reach height. Following measurement of reach height, each subject was instructed to stand directly under the Vertec blades in the same location as the standing reach height measurement and perform a countermovement jump with an arm swing, both at self selected speed. At the highest portion of the jump the subject reached with the dominant hand and tapped the highest blade. The difference in vertical distance between standing reach height and the highest blade touched (jump height) was recorded as VJ_{height}. Following each jump the blades of the Vertec below the previous attempt were moved to encourage the participant to reach higher on the subsequent attempt. Each subject performed a minimum of three attempts, with 30 seconds of seated rest provided prior to each attempt. An attempt was defined as a countermovement jump with proper form. If on the third attempt, the jump height increased, the subject rested and performed another attempt. This continued until the subject was unable to increase jump height. The highest value attained, to the nearest half-inch was recorded as VJ_{height} and later converted to cm. This measurement was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

10-Meter Sprint Velocity

V_{10m} was determined using an infrared laser-timing device (Brower Timing Systems, Draper, UT). Each subject was instructed to stand in a sprinter's stance with the front foot on a touch sensitive mat that started on release. On the subject's go they sprinted a distance of 10 meters as fast as they could. Each subject performed two trials with approximately 30 seconds rest provided between trials. The fastest time to sprint 10 meters was recorded and rounded to the nearest one-hundredth. This measurement was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

Soreness Measurements

Soreness of elbow flexor and knee extensor muscles was determined by having subjects rate the degree of local muscle soreness from 0 to 10 using a visual analog scale (VAS), with 0 described as "no soreness" and 10 described as "unbearable soreness" (Figure 2). This rating was obtained before all performance measurements and was assessed by performing bilateral isometric elbow extension, unloaded concentric elbow flexion, unloaded squat and unloaded concentric knee extension.

Isometric Elbow Extension Soreness

Isometric elbow extension soreness was performed bilaterally on the same modified preacher curl apparatus used for isometric EF strength tests. With the subject seated, a member of the research team would instruct the subject to extend the elbow to complete extension. Once in the position of complete elbow extension perceived soreness measurement was recorded by having the subject rate the degree of soreness at complete elbow extension using the VAS. This test was performed at PRE, and 2h, 24h, 48h, 72h, 96h post-exercise.

Unloaded Elbow Flexion Soreness

Unloaded elbow flexion soreness was performed bilaterally on the same modified preacher curl apparatus used for isometric strength tests of the elbow flexors. With the subject seated, a member of the research team instructed the subject to concentrically contract the elbow flexors from complete elbow extension to complete flexion. Following movement into complete elbow flexion, perceived soreness was recorded by having the subject rate the degree of soreness throughout the entire movement using the VAS. This test was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

Unloaded Squat Soreness

Unloaded squat soreness was measured by having the subject perform a squat from standing position to a predetermined height and return to a standing position. Once in the subject returned to the standing position perceived soreness was recorded by having the subject rate the degree of soreness throughout the entire movement using the VAS. This test was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

Isometric Knee Extension Soreness

Isometric knee extension soreness was measured bilaterally using the same modified knee extension apparatus as used for isometric strength tests of the knee extensors. Each subject was strapped into the knee extension device at the waist and shoulders. With the subject seated, a member of the research team would instruct the subject to extend the knee to complete extension. Once in the position of complete knee extension perceived soreness measurement was recorded by having the subject rate the degree of soreness using the VAS. This test was performed at PRE, 2h, 24h, 48h, 72h, and 96h post-exercise.

FAMILIARIZATION

Prior to the start of the experimental protocol subjects reported to the human performance laboratory at The University of Texas at Austin on three occasions to familiarize themselves with the testing procedures. Familiarization trials were required to ensure each subject was comfortable and able to perform maximally on all measurements. Three total trials were performed at least 24 hours apart. The day of the final familiarization trial was considered Day 1 of the experimental protocol. All settings for soreness and performance measurement devices were recorded and replicated during ever testing session of the experimental protocol.

1-RM TESTING

Prior to the performing eccentric contractions of the elbow flexors, each subject's 1-RM was determined. 1-RM was determined by having the subject perform one bilateral elbow flexion concentrically using a weight that was approximately 80% of their maximal isometric elbow flexor strength. Weight was increased dependent on the participant's perceived level of difficulty, until failure occurred. The highest weight able to be lifted through the entire range of motion was considered the subject's 1-RM. The subject was allowed 60 seconds rest between attempts. Approximately five minutes following the final attempt the subjects began the eccentric exercise protocol.

STATISTICAL ANALYSIS

Two-way ANOVA was used for treatment, time, and treatment X time effects for performance measurements (% of PRE) and muscle soreness. The Bonferroni post-hoc analysis was applied. Significance was assessed at alpha level of $p < 0.05$. Values were reported as mean ± *SEM*.

RESULTS

SUBJECTS

There were no significant differences between 1x, 2x or PLA treatment groups for subjects' age (22.1 ± 1.0 vs. 22.5 ± 1.4 vs. 22.2 ± 0.6 y, respectively, $p > 0.05$), height (173.90 ± 1.2 vs. 176.3 ± 1.6 vs. 175.5 ± 1.3 cm, respectively, $p > 0.05$) or weight (72.1 ± 2.2 vs. 74.4 ± 3.2 vs. 74.9 ± 3.4 kg, respectively, $p > 0.05$).

ECCENTRIC EXERCISE

All subjects completed both eccentric exercise protocols with downhill running preceding eccentric contractions of the elbow flexors in all conditions. Downhill running speed was not significantly different between 1x, 2x, and PLA treatments (7.6 ± 0.03 vs. 7.6 ± 0.1 vs. 7.7 ± 0.1 mph, respectively; $p > 0.05$). Weight used for eccentric contractions of the elbow flexors was no different between 1x, 2x, and PLA treatments (31.8 ± 2.1 vs. 30.6 ± 2.1 vs. 30.6 ± 1.6 kg, respectively; $p > 0.05$). All subjects completed 40 repetitions of eccentric elbow flexion using the weight lifted for concentric 1-RM, therefore there was no difference in volume completed between 1x, 2x, and PLA treatment (1272.7 ± 85.1 vs. 1224.2 ± 82.2 vs. 1224.2 ± 65.1 kg, respectively, $p > 0.05$).

Performance Measurements

Performance measurements were normalized to maximal value measured in 0-hour testing session and reported as a percentage of that level (%).

Isometric Knee Extensor Strength

Isometric KE strength during the 2- to 96-hour post-exercise period was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 93.9 ± 1.5% vs. 91.6 ± 1.5% vs. 87.1 ± 1.8%, respectively; $p < 0.001$). Both 1x and 2x treatments were significantly higher than PLA ($p < 0.001$ and $p = 0.004$, respectively). There was no significant difference between 1x and 2x treatments ($p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.05$). At the 2-hour time point isometric knee extension strength was significantly reduced in 1x, 2x, and PLA treatments compared with 0-hour time point (88.9 ± 2.3%, 87.4 ± 1.6%, and 86.7 ± 2.5%, respectively; $p < 0.05$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 7).

Isometric Elbow Flexor Strength

Isometric EF strength during the 2- to 96-hour post-exercise period was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 83.6 ± 2.7% vs. 85.6 ± 1.9% vs. 78.4 ± 1.8%, respectively; $p < 0.001$). Both 1x and 2x treatments were significantly higher than PLA ($p = 0.004$ and $p < 0.001$, respectively). There was no significant difference between 1x and 2x treatments ($p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.001$). At 2-hour time point isometric elbow flexion strength was significantly reduced in 1x, 2x, and PLA treatments compared with 0-hour time point (73.5 ± 2.8%, 76.7 ± 2.1%, and

74.9 ± 2.0%, respectively; $p < 0.001$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 8).

INERTIAL LOAD MAXIMAL CYCLING POWER

P_{max} during the 2- to 96-hour post-exercise period was not significantly different between 1x, 2x, and PLA treatments (main treatment effect, 96.3 ± 1.2% vs. 95.5 ± 1.2% vs. 94.6 ± 0.7%, respectively; $p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in 2x and PLA treatments ($p < 0.05$), while no effect of time was present in 1x treatment ($p > 0.05$) (Figure 9). IP_{max} was not significantly different between 1x, 2x, and PLA treatment (main treatment effect, 96.9 ± 1.4% vs. 98.6 ± 1.8% vs. 98.3 ± 1.7%, respectively; $p > 0.05$) during the PRE to 96-hour period after exercise (Figure 10). V_{maz} was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 100.9 ± 1.6% vs. 98.2 ± 1.1% vs. 100.6 ± 1.8%, respectively; $p = 0.037$) during the PRE to 96-hour period after exercise. The 1x treatment was significantly greater than 2x treatment ($p = 0.047$), but was not different than PLA ($p = 1.000$), while there was a trend for PLA to be greater than 2x ($p = 0.084$) (Figure 11). T_{max} was not significantly different between 1x, 2x, and PLA treatments (main treatment effect, 96.6 ± 1.8% vs. 98.6 ± 1.7% vs. 95.8 ± 2.2%, respectively; $p > 0.05$) during the PRE to 96-hour period after exercise (Figure 12). T_0 was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 117.0 ± 10.8% vs. 100.3 ± 5.2% vs. 101.9 ± 7.3%, respectively; $p = 0.002$) during the PRE to 96-hour period after exercise. The 1x treatment was significantly greater than both 2x and PLA treatment ($p = 0.030$ and 0.010, respectively) (Figure 13). There was no effect of time on IP_{max}, V_{max}, T_{max} or T_0 throughout the PRE to 96-hour period after exercise ($p > 0.05$).

VERTICAL JUMP HEIGHT

VJ_{height} during the 2- to 96-hour post-exercise period was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 99.9 ± 0.9% vs. 99.5 ± 1.0% vs. 98.0 ± 1.0%, vs. respectively; $p = 0.031$). The 1x treatment was significantly greater than PLA ($p = 0.037$), while the 2x treatment was not significantly different than 1x or PLA treatments ($p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in 1x and 2x treatments ($p < 0.05$), while no effect of time was present with the PLA treatment ($p > 0.05$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 14).

10-METER SPRINT VELOCITY

V_{10m} during the 2- to 96-hour post-exercise period was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 100.0 ± 0.8% vs. 98.9 ± 0.5% vs. 97.8 ± 0.7%, respectively; $p = 0.019$). The 1x treatment was significantly greater than PLA ($p = 0.003$), while the 2x treatment was not significantly different than 1x or PLA treatments ($p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period between all treatments ($p = 0.004$), however no time effect existed in any individual treatment ($p > 0.05$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 15).

Soreness Measurements

Soreness was reported on a visual analog scale (VAS) of 0-10 (Figure 2). A value of 0 indicating "no soreness" and 10 indicating "unbearable soreness."

ELBOW EXTENSION SORENESS

Elbow Extension soreness during the 96-hour post-exercise period was not significantly different between 1x, 2x, and PLA treatments (main treatment effect, 2.4 ± 0.4 vs. 2.1 ± 0.3 vs. 2.1 ± .02, respectively; $p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.001$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 3).

ELBOW FLEXION SORENESS

Elbow flexion soreness during the 96-hour post-exercise period was not significantly different between 1x, 2x, and PLA treatments (main treatment effect, 2.6 ± 0.3 vs. 2.4 ± 0.2 vs. 2.4 ± 0.3, respectively; $p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.001$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 4).

UNLOADED SQUAT SORENESS

Unloaded squat soreness during the 96-hour post-exercise period was not significantly different between 1x, 2x and PLA treatments (main treatment effect, 2.0 ± 0.3 vs. 2.0 ± 0.2 vs. 2.0 ± 0.3, respectively; $p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.001$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 5).

KNEE EXTENSION SORENESS

Knee extension soreness during the 96-hour post-exercise period was significantly different between 1x, 2x, and PLA treatments (main treatment effect, 1.9 ± 0.3 vs. 1.5 ± 0.3 vs. 1.4 ± 0.3, respectively; $p = 0.044$). The 1x treatment group had significantly higher values for soreness than the PLA treatment ($p = 0.045$), while 2x as compared to 1x or PLA did not differ in treatment effect ($p > 0.05$). Two subjects in the 1x treatment group rated soreness pre-exercise at values two to three standard deviations higher than the mean. This may have skewed the data. All subsequent soreness measurements taken at this measurement in these individuals were typically higher than the mean response. When these subjects are removed there is no difference between groups ($p > 0.05$). There was an overall time effect of exercise during the 96-hour testing period in all treatments ($p < 0.001$). There was no treatment X time effect between treatments ($p > 0.05$) (Figure 6).

DISCUSSION

The primary finding in this study was that both once daily (1x) and twice daily (2x) dietary supplementation with pomegranate juice concentrate (PJC) results in significantly higher for isometric knee extensor (KE) and elbow flexor (EF) strength throughout the 96-hour period following eccentric exercise, as compared to placebo (PLA). Secondary findings indicate that 1x PJC may be a more optimal dose as 10-meter sprint velocity (V_{10m}) and vertical jump height (VJ_{height}) throughout the 96-hour period following eccentric exercise were higher than those of PLA, while the 2x was not significantly different than PLA.

There are a small numbers of studies available that have tested the effects of polyphenol supplementation on recovery from eccentric exercise in humans, the majority of which are in agreement with our findings [20, 21, 23, 28-30]. To the best of our knowledge recovery from downhill running has never been tested with any type of polyphenol supplementation. However, the effect of polyphenol supplementation on recovery from running of extreme distances (i.e. marathon) has displayed positive effects [23, 24]. Of the studies that have tested the effects of polyphenol supplementation on isometric strength recovery following maximal eccentric contractions, two studies had subjects supplement with pomegranate polyphenols [21, 29, 30]. Our study supports the findings of both of these studies while demonstrating a lower dose may be all that is needed Although, one study not shown a beneficial effect for isometric knee extensor strength following eccentric exercise in resistance trained athletes [30]. This study tested untrained individuals performing downhill running, therefore limited comparisons can be made.

Isometric strength is a direct reflection of muscle damage following eccentric exercise. Force loss due to muscle damage may be proportionate to the amount of muscle damage attained. Therefore we can relate and compare the amount of muscle damage attained by observing isometric strength loss and recovery between groups [74]. In this study, isometric strength loss two hours after exercise was similar between all groups in both elbow flexors and knee extensors. As strength loss was no different between groups, the extent of damage was no different between groups. The range of decreases for Isometric EF and KE strength for all treatments decreased to values of 73-77% and 87-89%, respectively. A loss of strength of this magnitude at two hours post eccentric exercise is in agreement with other studies using similar methods [21, 29, 52, 57]. In the 24 hours following exercise, isometric EF and KE strength increased for both 1x and 2x PJC, this was not the case for PLA (Figure 8 & 9). Interestingly, although not significantly different, PLA isometric strength decreased over this time period for both isometric EF and KE strength.

Immediately following unaccustomed eccentric exercise, neutrophils are signaled and accumulate at the site of injury to phagocytose and set the stage for regeneration of the damaged tissue [14, 17, 18, 66, 67]. Neutrophils, although necessary for recovery, may actually contribute to secondary damage, as hours after while they phagocytose damaged tissue, they release reactive oxygen species (ROS) [14, 15, 68]. Excessive oxidative stress caused by ROS may cause secondary damage to muscle tissue that was previously being regenerated. The secondary damage again signals neutrophils to the site of injury, [69]. Dietary supplementation of both 1x and 2x PJC may be sufficient to mitigate the extent of secondary damage.

Typically 24 hours following eccentric exercise strength remains lower than pre-exercise values [4]. Previous studies that test isometric strength multiple times within the first 24 hours following exercise have shown a bimodal rate of recovery. Between 6-12 hours following the bout, as strength is being recovered there is an additional decrease in strength [13, 38]. This second decrease in strength that occurs is due to sum of accumulation of inflammatory and oxidative stress at the site of injury. This response has only been shown following isolated maximal eccentric contractions of the knee extensors. However, there is no reason to discount that its occurrence would not be present following eccentric contractions of the elbow flexors or downhill running, as this type of inflammatory signaling to the initial site of injury occurs in all individuals performing any bout of novel eccentric exercise.

Although there were no differences between treatments observed in inertial load maximal cycling power (P_{max}), when analyzing the individual factors that determine P_{max}, some differences exist. No differences were observed between treatments for maximal instantaneous power (IP_{max}) or maximal torque (T_{max}), however there were effects of treatment on maximal velocity (V_{max}) and torque at 0° (T_0). Values for 1x PJC were higher than 2x PJC for V_{max}; T_0 was also higher for 1x PJC as compared to 2x and PLA. While no difference existed for V_{max} between 1x and PLA, PLA trended towards being higher than 2x. ($p = 0.084$).

As stated above, values for V_{10m} were also higher in 1x PJC as compared to PLA, however before further speculation on why this is, the secondary results from the inertial load power cycle test should be included in this explanation. V_{max} and T_0 were both higher in 1x PJC, as compared to 2x PJC, with T_i being higher in 1x as compared to PLA as well. The measurement for V_{10m} is a value that indicates the individual's ability to accelerate from over 10 meters from a standing position. The initiation of power generation needed to accelerate in this measure is similar to the T_i that needs to be generated to produce P_{max}. It can therefore be reasonably postulated that higher values for V_{10m} in the 1x PJC treatment are due to an increased ability to generate T_0. This may shed some light on why the 1x PJC treatment results in higher V_{10m} values two hours after exercise. It is not able to be determined in this current study why 1x PJC treatment displays higher values for V_{max} and T_0 compare to 2x PJC treatment. It is possible that while 1x PJC protects the individual from extensive secondary damage, the 2x PJC may overprotect, hindering training adaptations.

In conclusion, 1x and 2x PJC supplementation were effective in eliciting higher values of isometric EF and KE strength, compared to PLA, throughout the 96-hours following eccentric exercise. Although PJC supplementation does not affect soreness, once per day supplementation of PJC is equally effective as twice per day for recovery of isometric strength in the four days after eccentric exercise.

APPENDIX A - FIGURES

Figure Legends

Figure 1: Testing Schedule

Figure 2: Visual Analog Scale (VAS)

Figure 3: Muscle soreness at complete elbow extension reported on a visual analog scale from 0 to 10. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 4: Muscle soreness during unloaded elbow flexion reported on a visual analog scale from 0 to 10. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 5: Muscle soreness during unloaded squat reported on a visual analog scale from 0 to 10. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 6: Muscle soreness at complete knee extension reported on a visual analog scale from 0 to 10. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). * 1x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 7: Isometric knee extensor (KE) strength expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). * 1x significantly higher than PLA, overall treatment

effect ($p < 0.05$). † 2x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 8: Isometric elbow flexor (EF) strength expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). * 1x significantly higher than PLA, overall treatment effect ($p < 0.05$). † 2x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 9: Inertial load maximal cycling power (P_{max}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 10: Inertial load maximal instantaneous power (IP_{max}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 11: Inertial load maximal velocity (V_{max}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). ‡ 1x significantly higher than 2x, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 12: Inertial load maximal torque (T_{max}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). Values are reported as mean ± *SEM*.

Figure 13: Inertial load torque at 0˚ (T_0) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). ‡ 1x significantly higher than 2x, overall treatment effect ($p < 0.05$). * 1x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 14: Vertical jump height (VJ_{height}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). * 1x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 15: 10-meter sprint velocity (V_{10m}) expressed as a percent of pre-exercise values. Treatments were once-daily (1x) or twice daily (2x) pomegranate juice concentrate or placebo (PLA). * 1x significantly higher than PLA, overall treatment effect ($p < 0.05$). Values are reported as mean ± *SEM*.

Figure 1 – Eight Day Testing Period

Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
			S, EE, S	S	S	S	S
Twice Daily Supplementation (1x, 2x, or PLA)							

S – Soreness and Performance Measurements

EE – Eccentric Exercise

Figure 2 – Visual Analog Scale

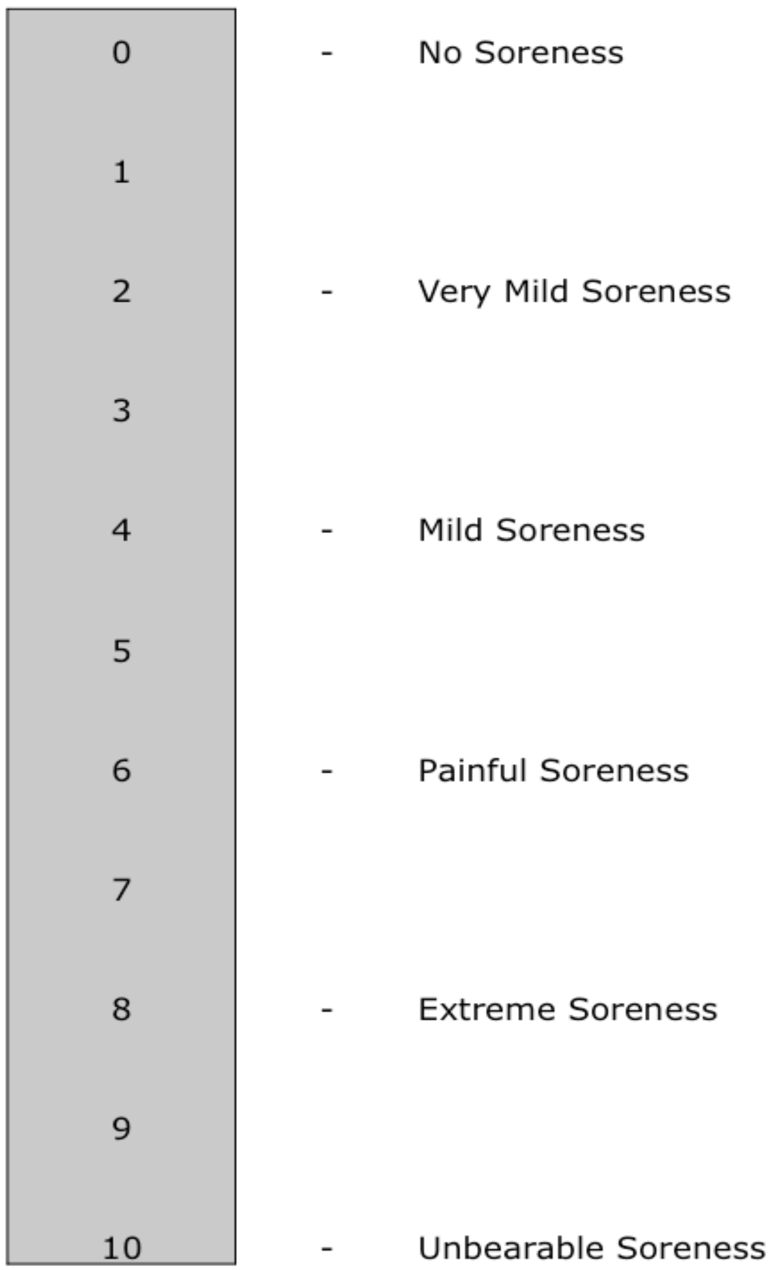


Figure 3 – Elbow Extension Soreness

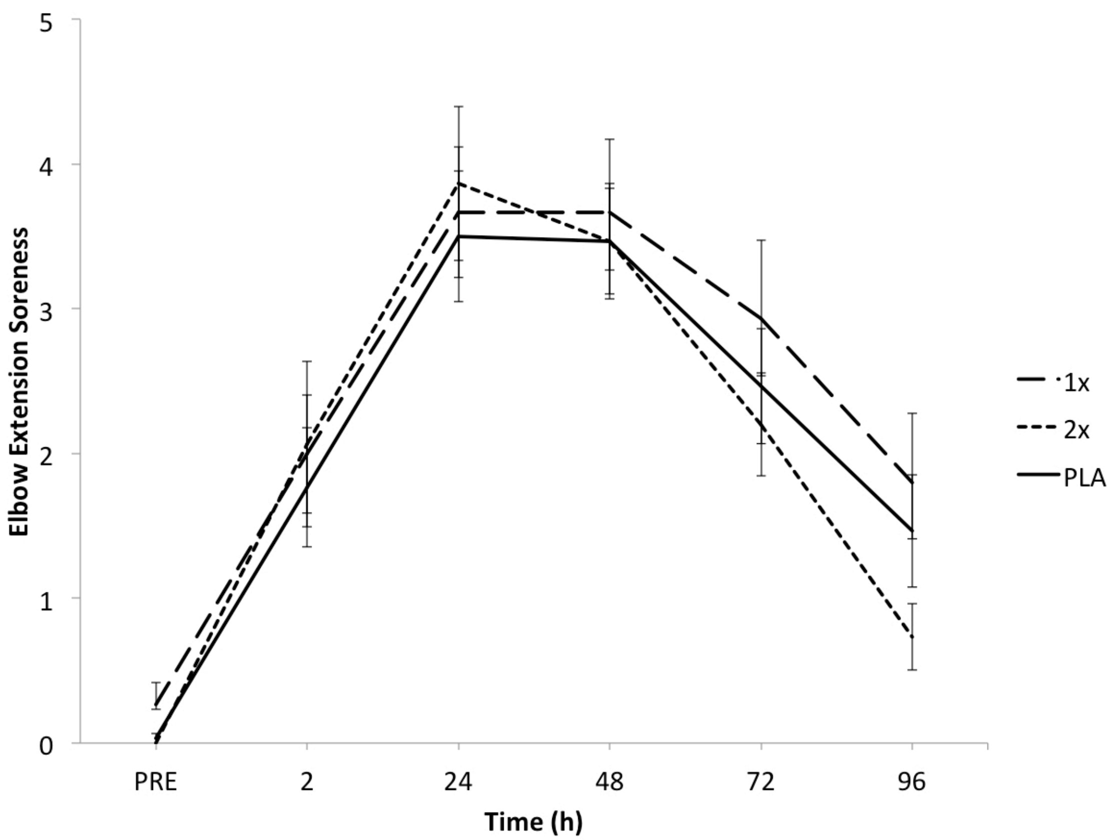


Figure 4 – Unloaded Elbow Flexion Soreness

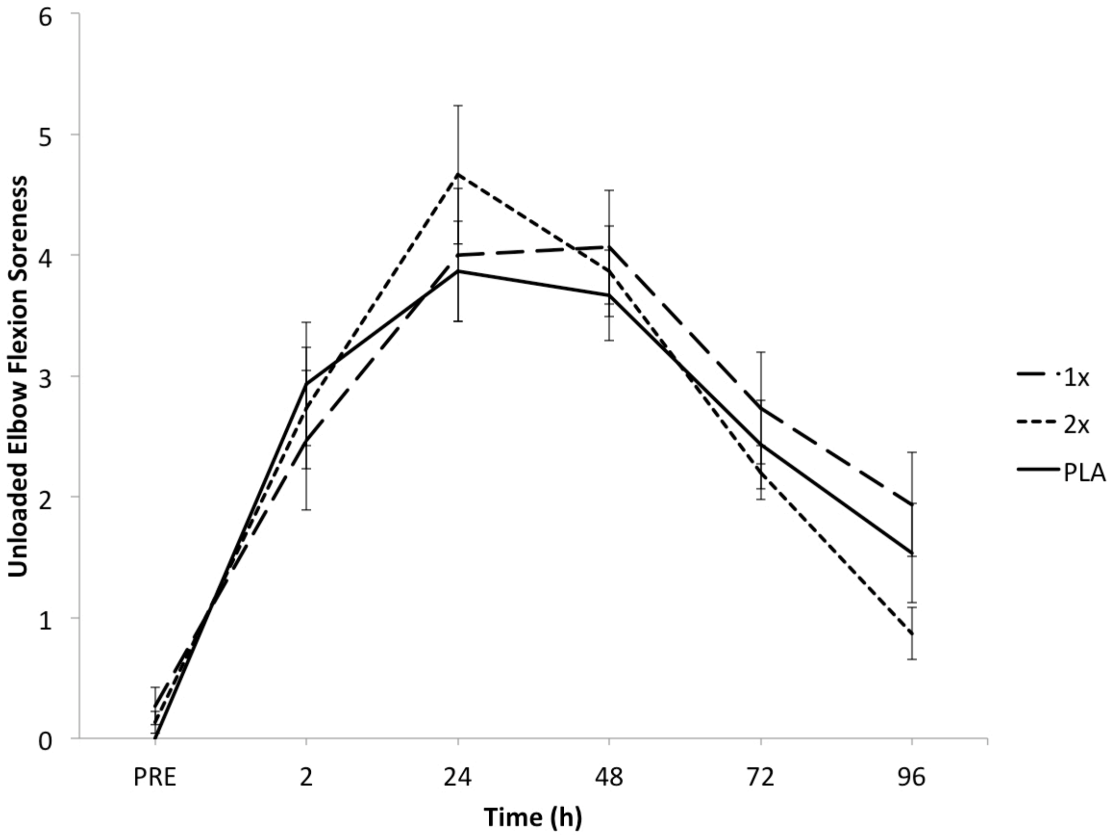


Figure 5 – Unloaded Squat Soreness

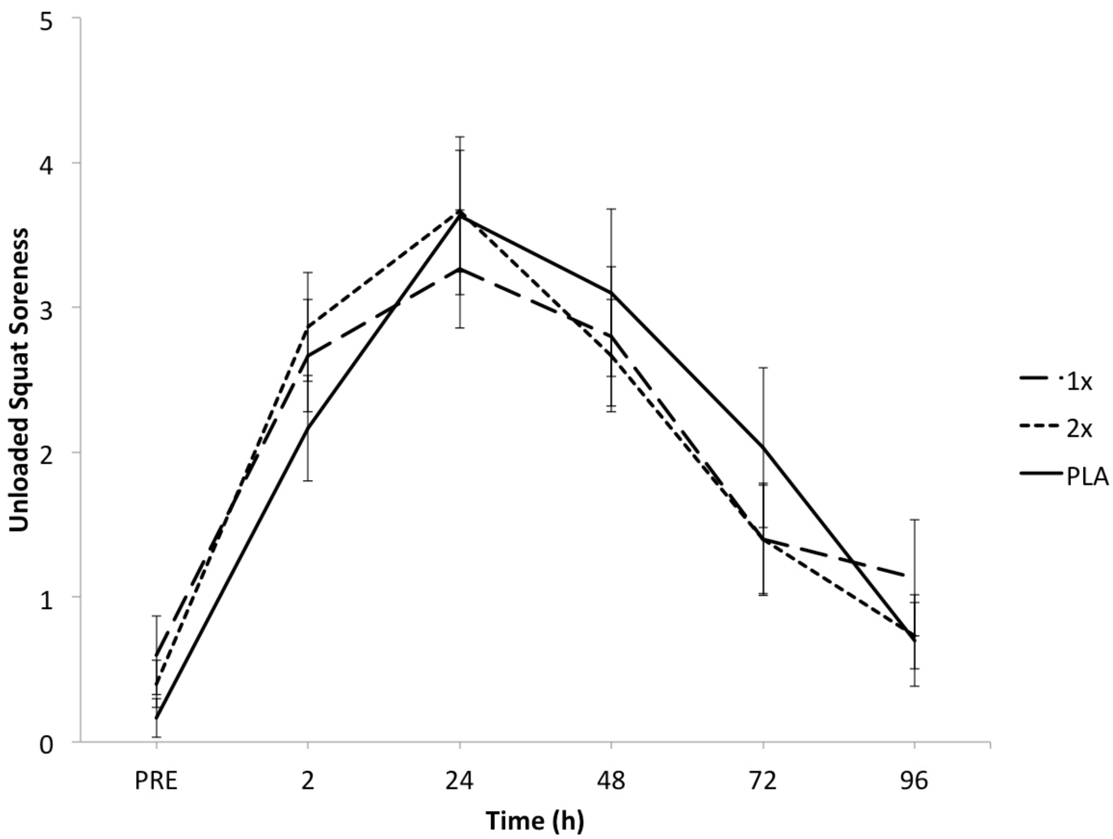


Figure 6 – Knee Extension Soreness

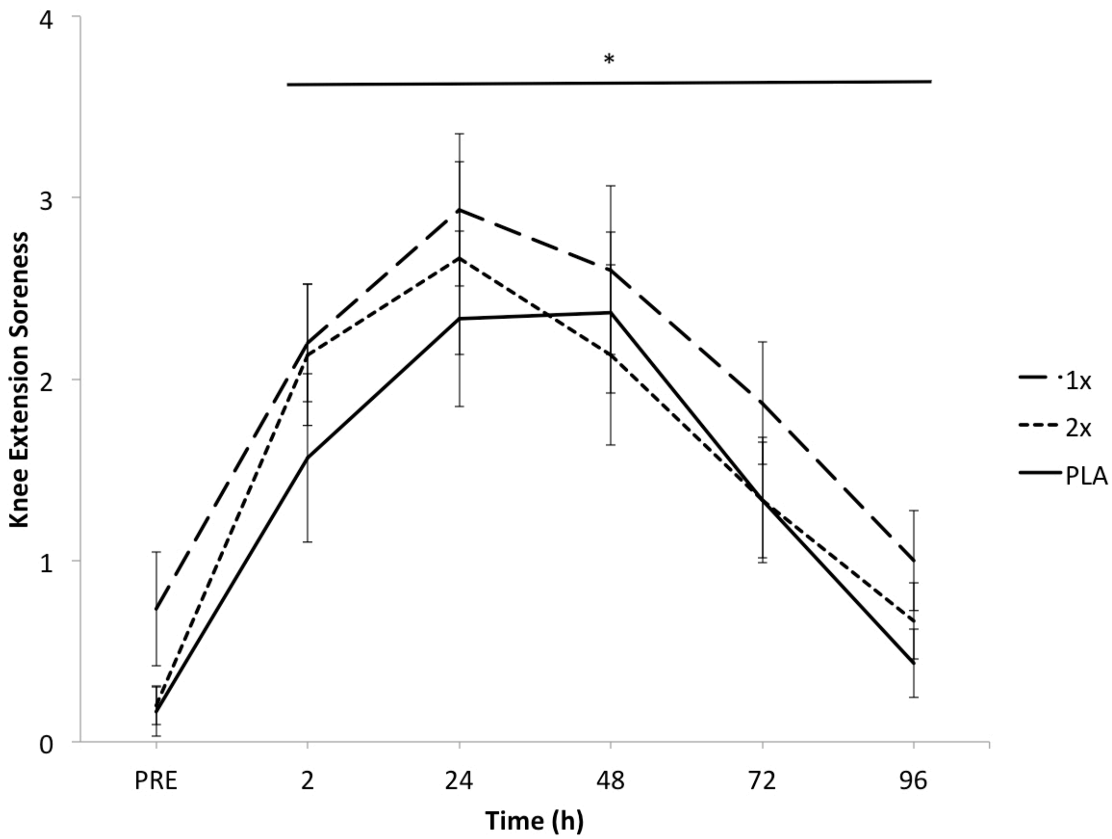


Figure 7 – Isometric Knee Extension Strength

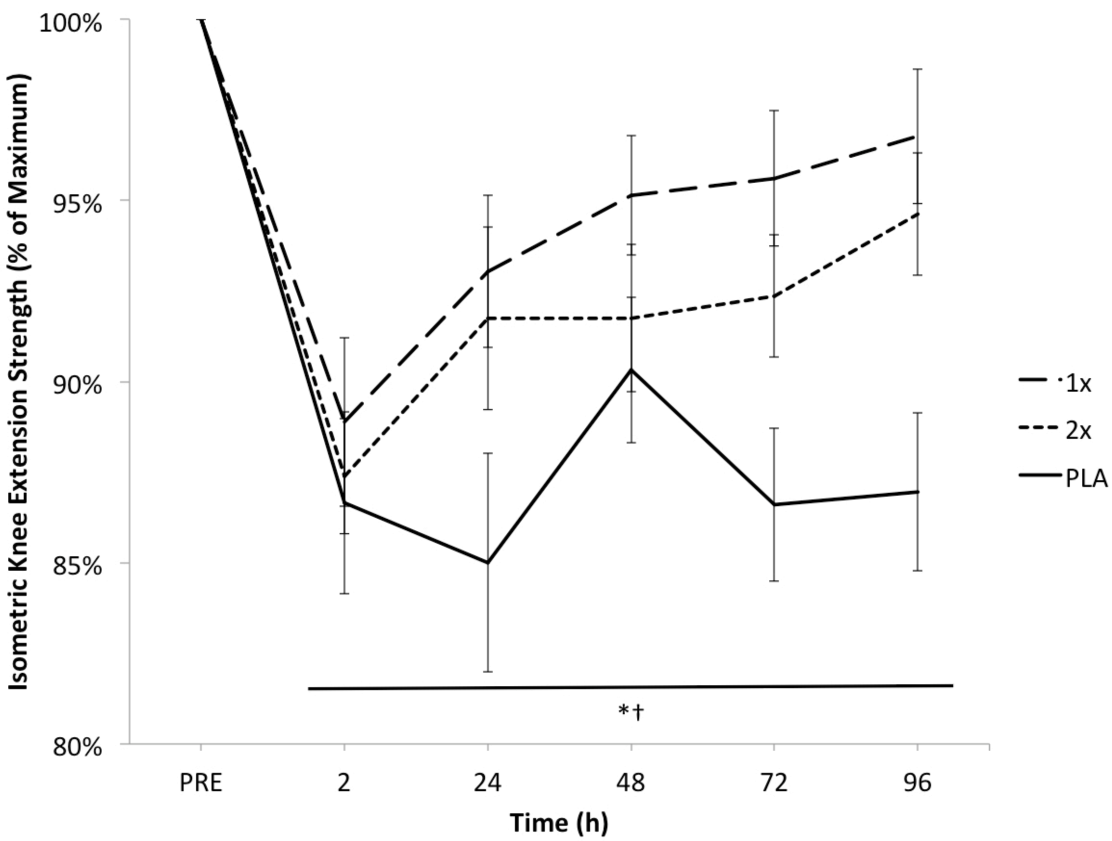


Figure 8 – Isometric Elbow Flexion Strength

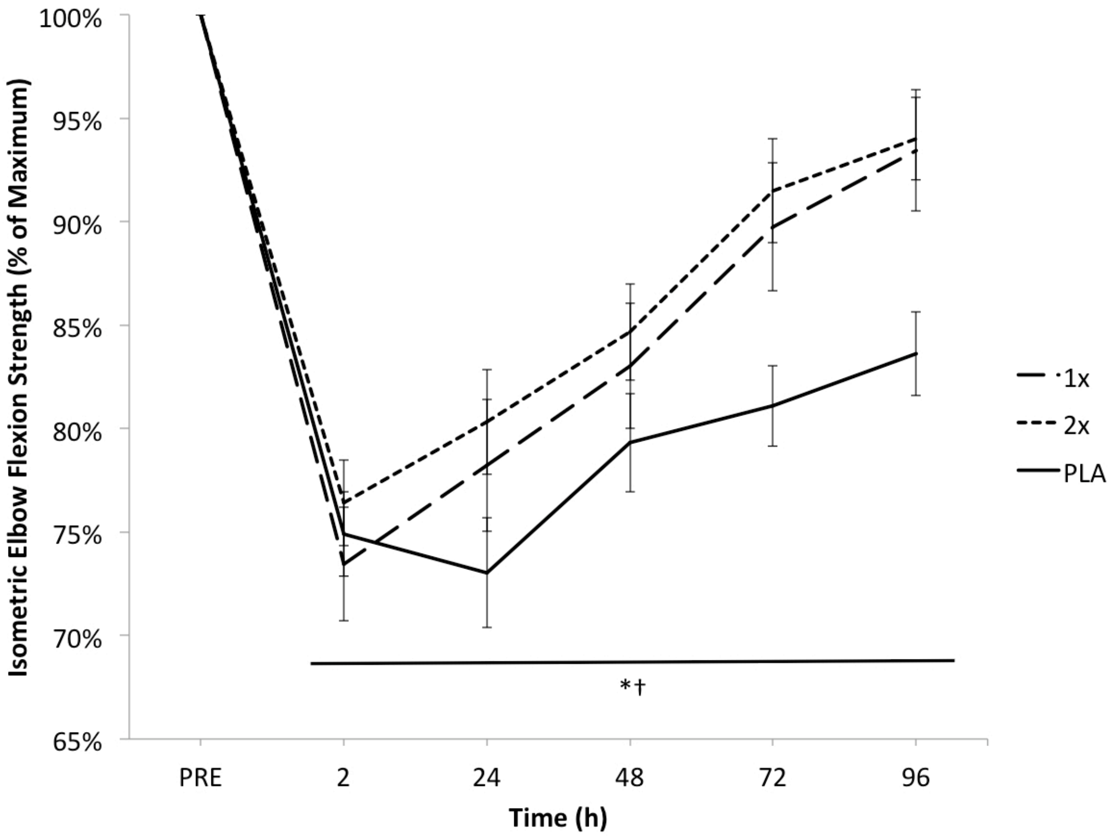


Figure 9 – Maximal Cycling Power

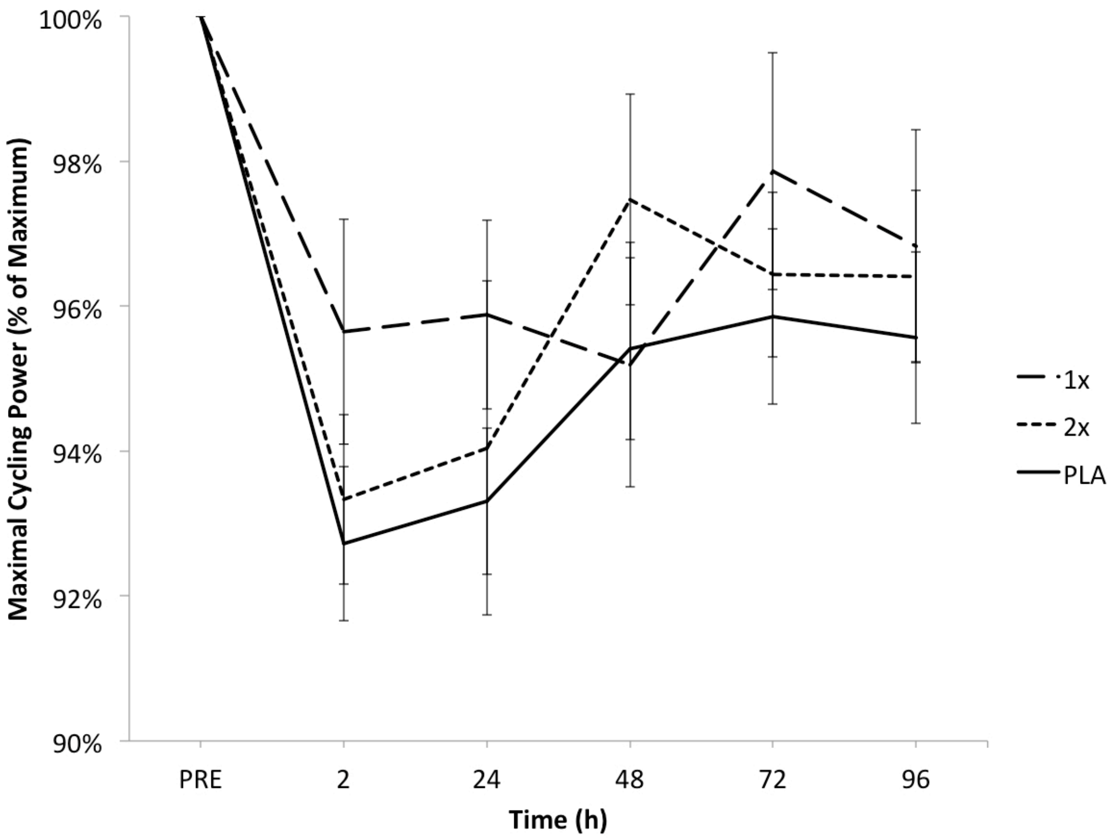


Figure 10 – Maximal Instantaneous Power

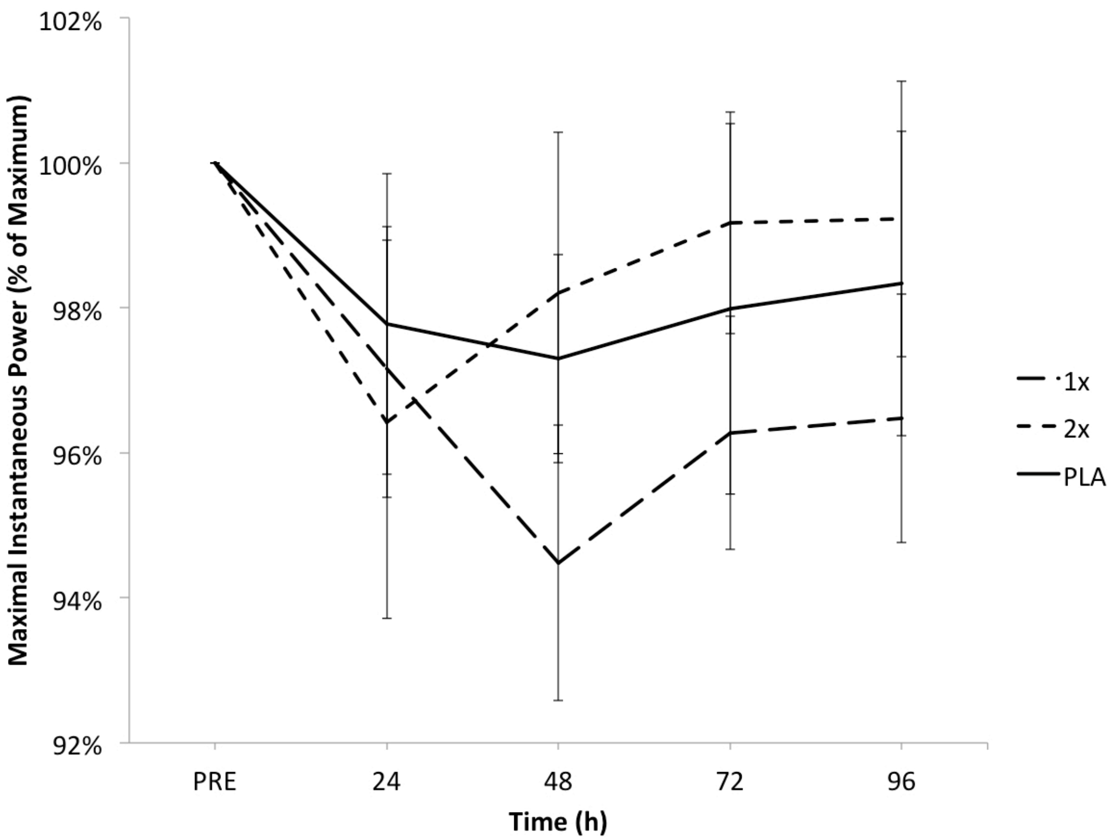


Figure 11 – Maximal Velocity

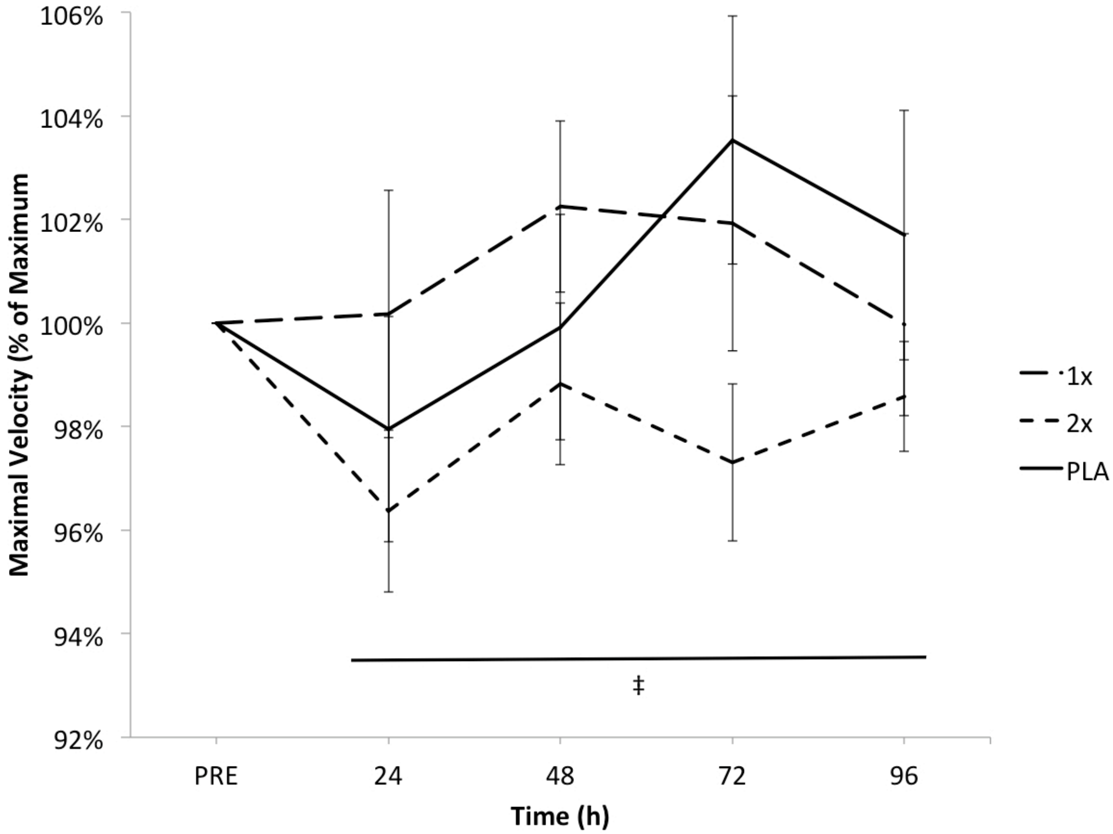


Figure 12 – Maximal Torque

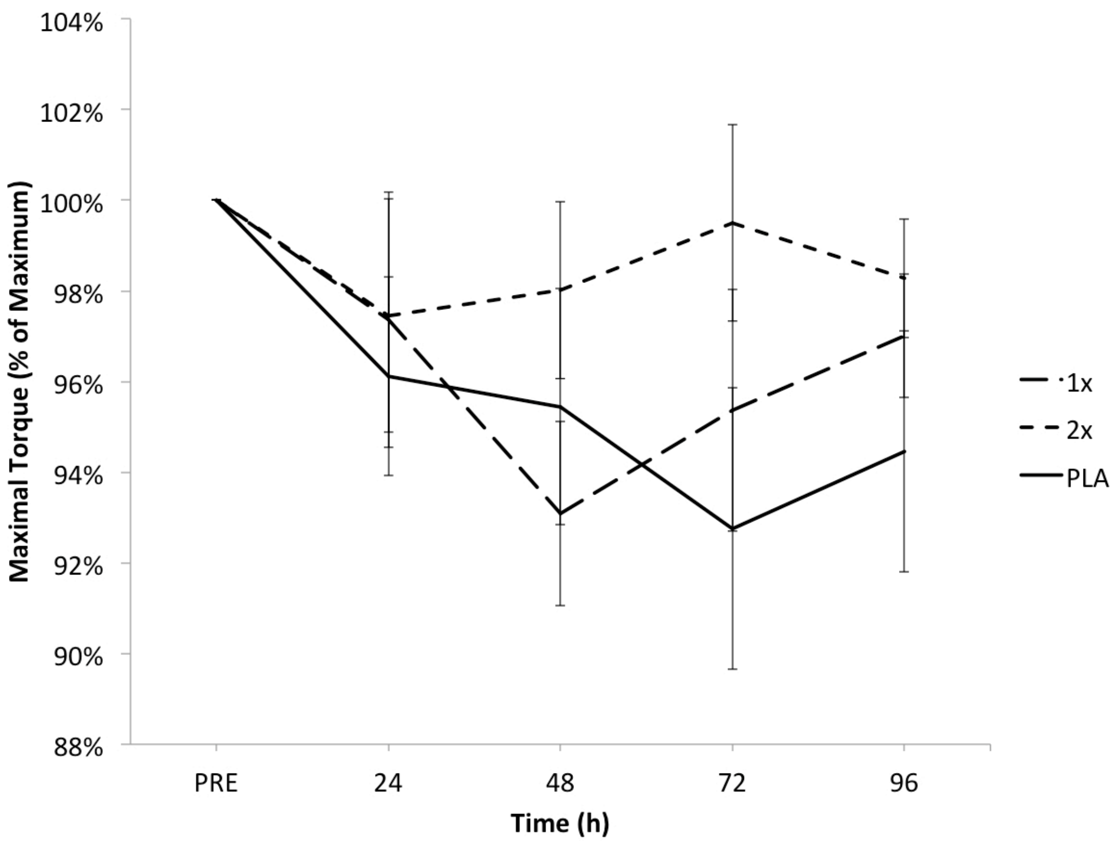


Figure 13 – Torque at 0˚

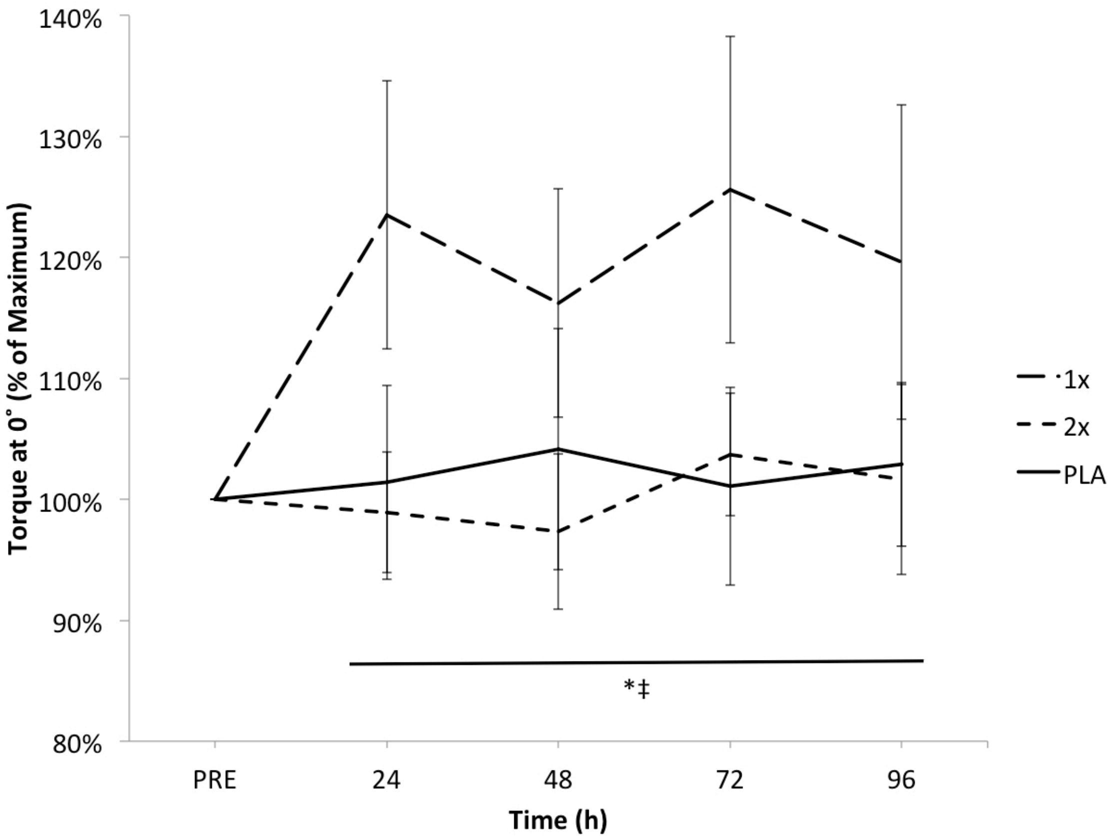


Figure 14 – Vertical Jump Height

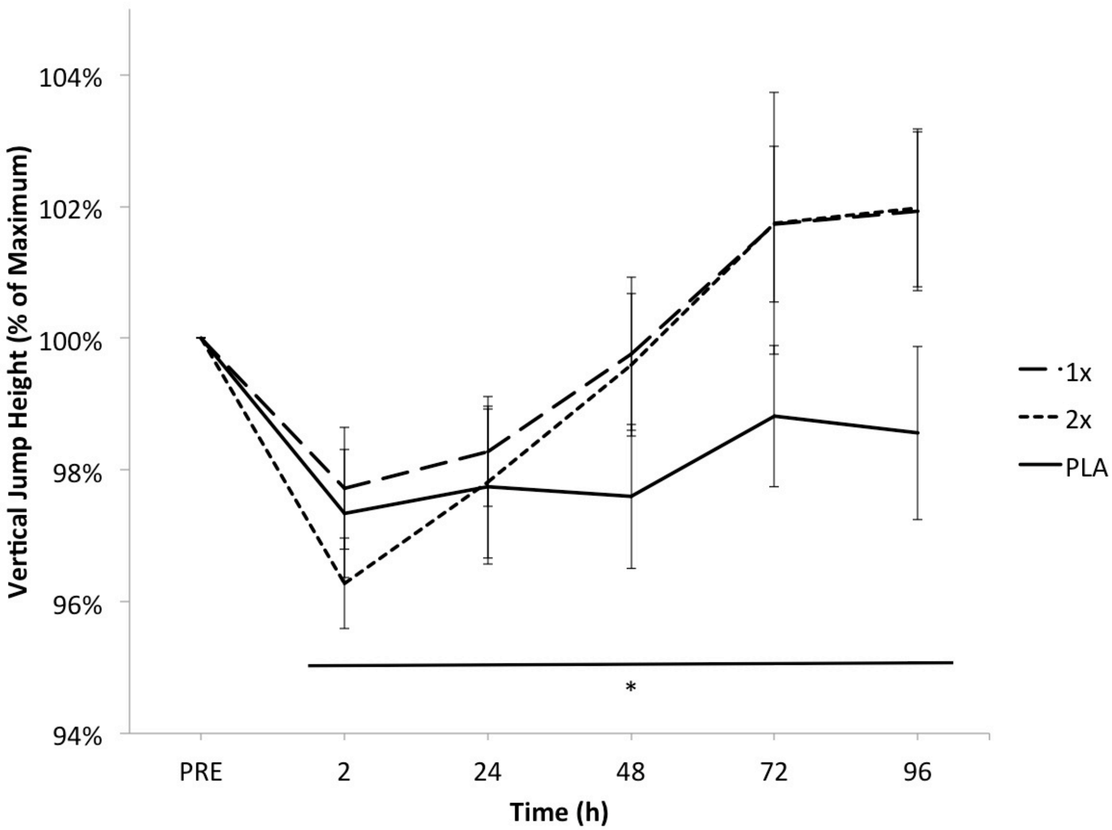
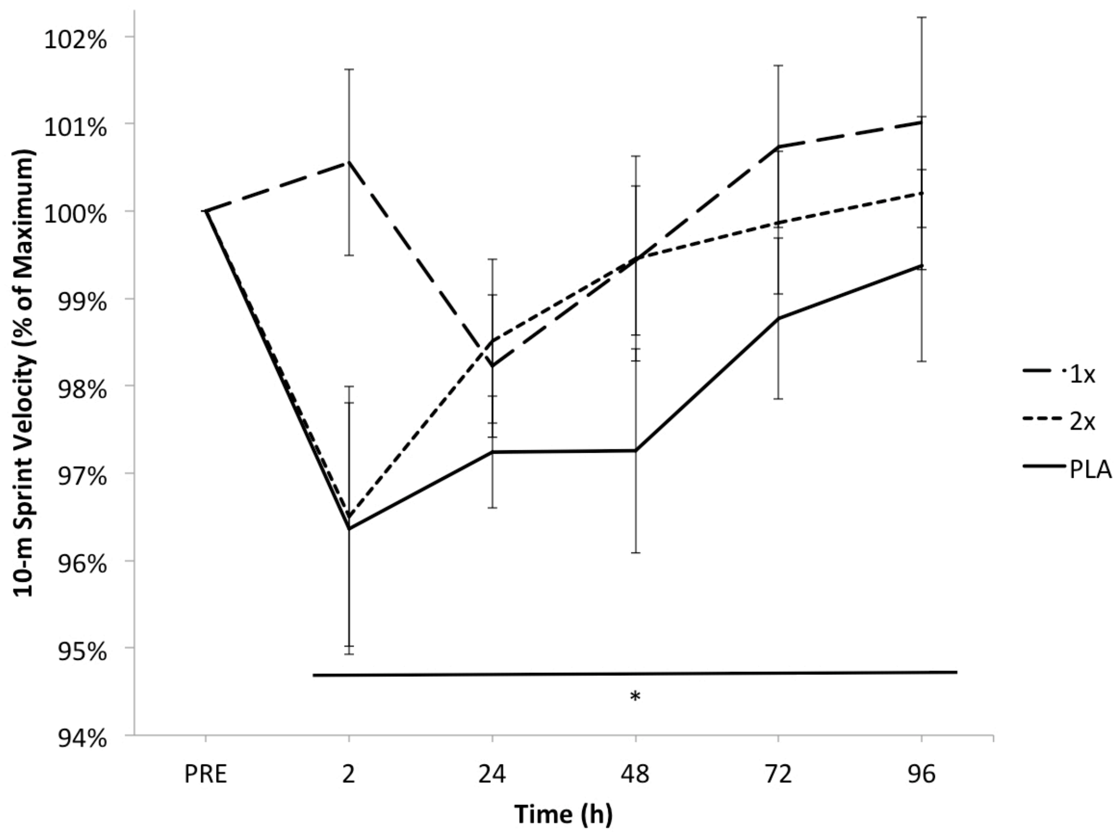


Figure 15 – 10-m Sprint Velocity



APPENDIX B – RAW DATA

Elbow Extension Soreness

Elbow Flexion Soreness

Unloaded Squat Soreness

Knee Extension Soreness

Isometric Knee Extension Strength

Isometric Elbow Flexion Strength

Inertial Load Maximal Cycling Power

Maximal Instantaneous Power

Maximal Velocity

Maximal Torque

Torque at 0°

Vertical Jump Height

10-Meter Sprint Velocity

Elbow Extension Soreness

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	1.0	2.0	2.0	4.0	1.0	1.0
9	0.0	1.0	4.0	4.0	3.0	2.0
11	0.0	1.0	1.0	0.0	0.0	0.0
13	0.0	2.0	4.0	5.0	6.0	4.0
17	2.0	2.0	4.0	3.0	2.0	2.0
20	0.0	3.0	5.0	3.0	2.0	0.0
26	0.0	0.0	4.0	5.0	4.0	1.0
29	0.0	0.0	1.0	0.0	0.0	0.0
32	0.0	4.0	5.0	6.0	4.0	3.0
35	1.0	1.0	2.0	2.0	1.0	0.0
38	0.0	2.0	3.0	3.0	2.0	0.0
41	0.0	5.0	6.0	6.0	7.0	6.0
44	0.0	4.0	6.0	6.0	5.0	4.0
48	0.0	3.0	6.0	5.0	4.0	3.0
49	0.0	0.0	2.0	3.0	3.0	1.0
Mean	**0.3**	**2.0**	**3.7**	**3.7**	**2.9**	**1.8**
SD	**0.6**	**1.6**	**1.8**	**2.0**	**2.1**	**1.9**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	0.0	2.0	4.0	4.0	1.0	1.0
6	0.0	2.0	3.0	4.0	3.0	2.0
8	0.0	1.0	4.0	3.0	1.0	0.0
10	0.0	4.0	5.0	4.0	2.0	0.0
14	0.0	2.0	7.0	5.0	5.0	1.0
16	0.0	0.0	3.0	4.0	4.0	2.0
19	0.0	5.0	6.0	5.0	3.0	1.0
25	0.0	3.0	8.0	4.0	3.0	0.0
28	0.0	1.0	2.0	3.0	2.0	0.0
31	0.0	0.0	3.0	1.0	0.0	0.0
34	0.0	0.0	1.0	1.0	2.0	0.0
40	0.0	8.0	4.0	5.0	3.0	0.0
43	0.0	2.0	5.0	5.0	2.0	2.0
46	0.0	0.0	1.0	2.0	2.0	2.0
47	0.0	1.0	2.0	2.0	0.0	0.0
Mean	**0.0**	**2.1**	**3.9**	**3.5**	**2.2**	**0.7**
SD	**0.0**	**2.2**	**2.1**	**1.4**	**1.4**	**0.9**

Elbow Extension Soreness

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	0.0	0.0	0.5	3.0	3.5	3.0
2	0.0	0.0	5.0	4.0	3.0	2.0
5	0.0	2.0	4.0	5.0	4.0	2.0
7	0.5	2.5	6.0	5.0	3.5	3.0
12	0.0	2.0	2.0	1.0	0.0	0.0
18	0.0	1.0	3.0	4.0	2.0	1.0
21	0.0	4.0	4.0	6.0	2.0	0.0
24	0.0	2.0	2.0	2.0	5.0	3.0
30	0.0	0.0	5.0	3.0	1.0	0.0
33	0.0	5.0	6.0	4.0	3.0	1.0
36	0.0	0.0	1.0	2.0	2.0	1.0
39	0.0	2.0	4.0	2.0	1.0	0.0
42	0.0	0.0	3.0	3.0	1.0	0.0
45	0.0	3.0	5.0	6.0	5.0	5.0
50	0.0	3.0	2.0	2.0	1.0	1.0
Mean	**0.0**	**1.8**	**3.5**	**3.5**	**2.5**	**1.5**
SD	**0.1**	**1.6**	**1.7**	**1.6**	**1.5**	**1.5**

Elbow Flexion Soreness

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	1.0	2.0	2.0	4.0	1.0	1.0
9	0.0	2.0	3.0	3.0	2.0	2.0
11	0.0	0.0	2.0	0.0	0.0	0.0
13	0.0	0.0	3.0	5.0	4.0	3.0
17	2.0	2.0	5.0	4.0	2.0	3.0
20	0.0	6.0	8.0	6.0	3.0	1.0
26	0.0	0.0	2.0	6.0	4.0	2.0
29	0.0	0.0	4.0	5.0	2.0	0.0
32	0.0	4.0	4.0	5.0	3.0	2.0
35	1.0	0.0	1.0	3.0	1.0	1.0
38	0.0	6.0	5.0	4.0	2.0	1.0
41	0.0	5.0	5.0	5.0	6.0	6.0
44	0.0	4.0	7.0	7.0	6.0	4.0
48	0.0	4.0	7.0	2.0	4.0	3.0
49	0.0	2.0	2.0	2.0	1.0	0.0
Mean	**0.3**	**2.5**	**4.0**	**4.1**	**2.7**	**1.9**
SD	**0.6**	**2.2**	**2.1**	**1.8**	**1.8**	**1.7**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	0.0	2.0	5.0	4.0	1.0	0.0
6	0.0	2.0	2.0	2.0	2.0	1.0
8	0.0	1.0	5.0	4.0	2.0	0.0
10	0.0	5.0	5.0	5.0	2.0	1.0
14	1.0	2.0	7.0	3.0	1.0	0.0
16	0.0	2.0	3.0	4.0	4.0	2.0
19	0.0	5.0	6.0	5.0	2.0	1.0
25	0.0	3.0	8.0	5.0	3.0	2.0
28	0.0	1.0	1.0	2.0	2.0	0.0
31	1.0	3.0	5.0	3.0	2.0	1.0
34	0.0	2.0	1.0	1.0	2.0	0.0
40	0.0	8.0	8.0	6.0	3.0	0.0
43	0.0	3.0	6.0	6.0	3.0	2.0
46	0.0	1.0	4.0	4.0	3.0	2.0
47	0.0	1.0	4.0	4.0	1.0	1.0
Mean	**0.1**	**2.7**	**4.7**	**3.9**	**2.2**	**0.9**
SD	**0.4**	**1.9**	**2.2**	**1.5**	**0.9**	**0.8**

Elbow Flexion Soreness

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	0.0	5.0	3.5	5.0	3.5	3.0
2	0.0	5.0	4.0	5.0	3.0	1.0
5	0.0	2.0	4.0	5.0	3.0	1.0
7	0.0	2.0	6.5	5.0	4.0	3.0
12	0.0	2.0	2.0	1.0	0.0	0.0
18	0.0	1.0	3.0	4.0	3.0	2.0
21	0.0	5.0	3.0	3.0	2.0	2.0
24	0.0	3.0	3.0	4.0	4.0	4.0
30	0.0	1.0	5.0	3.0	1.0	0.0
33	0.0	5.0	6.0	4.0	3.0	0.0
36	0.0	0.0	1.0	2.0	1.0	0.0
39	0.0	4.0	5.0	4.0	1.0	1.0
42	0.0	0.0	2.0	2.0	1.0	0.0
45	0.0	3.0	6.0	6.0	5.0	5.0
50	0.0	6.0	4.0	2.0	2.0	1.0
Mean	**0.0**	**2.9**	**3.9**	**3.7**	**2.4**	**1.5**
SD	**0.0**	**2.0**	**1.6**	**1.4**	**1.4**	**1.6**

Unloaded Squat Soreness

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	1.0	5.0	3.0	6.0	3.0	2.0
9	1.0	2.0	1.0	2.0	0.0	1.0
11	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	1.0	3.0	2.0	1.0	0.0
17	3.0	4.0	4.0	4.0	3.0	4.0
20	0.0	3.0	6.0	3.0	0.0	0.0
26	0.0	1.0	2.0	3.0	0.0	0.0
29	0.0	4.0	4.0	1.0	1.0	0.0
32	0.0	3.0	3.0	5.0	3.0	2.0
35	0.0	2.0	3.0	4.0	2.0	1.0
38	1.0	4.0	4.0	2.0	1.0	0.0
41	0.0	2.0	3.0	1.0	0.0	0.0
44	3.0	5.0	6.0	6.0	5.0	5.0
48	0.0	2.0	4.0	2.0	1.0	1.0
49	0.0	2.0	3.0	1.0	1.0	1.0
Mean	**0.6**	**2.7**	**3.3**	**2.8**	**1.4**	**1.1**
SD	**1.1**	**1.5**	**1.6**	**1.9**	**1.5**	**1.6**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	0.0	4.0	6.0	5.0	2.0	1.0
6	0.0	2.0	2.0	2.0	2.0	1.0
8	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	2.0	4.0	3.0	0.0	0.0
14	1.0	3.0	5.0	1.0	1.0	0.0
16	1.0	4.0	4.0	5.0	5.0	3.0
19	1.0	3.0	5.0	2.0	1.0	1.0
25	0.0	5.0	3.0	1.0	0.0	0.0
28	0.0	1.0	2.0	1.0	0.0	0.0
31	2.0	4.0	4.0	3.0	3.0	2.0
34	0.0	2.0	2.0	3.0	1.0	1.0
40	0.0	5.0	5.0	3.0	3.0	0.0
43	0.0	4.0	5.0	4.0	2.0	1.0
46	0.0	2.0	3.0	4.0	0.0	0.0
47	1.0	2.0	5.0	3.0	1.0	1.0
Mean	**0.4**	**2.9**	**3.7**	**2.7**	**1.4**	**0.7**
SD	**0.6**	**1.5**	**1.6**	**1.5**	**1.5**	**0.9**

Unloaded Squat Soreness

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	0.0	2.0	0.5	0.0	0.0	0.0
2	0.0	4.0	2.0	2.0	1.0	0.0
5	0.0	2.0	2.0	4.0	2.0	0.0
7	0.5	2.5	7.0	6.5	6.5	4.5
12	0.0	1.0	3.0	1.0	0.0	0.0
18	0.0	1.0	2.0	2.0	2.0	1.0
21	0.0	3.0	5.0	4.0	2.0	0.0
24	0.0	1.0	1.0	2.0	2.0	1.0
30	0.0	1.0	5.0	2.0	0.0	0.0
33	2.0	6.0	5.0	4.0	2.0	1.0
36	0.0	1.0	4.0	3.0	0.0	0.0
39	0.0	2.0	4.0	2.0	1.0	0.0
42	0.0	1.0	8.0	9.0	7.0	1.0
45	0.0	3.0	3.0	3.0	2.0	0.0
50	0.0	2.0	3.0	2.0	3.0	2.0
Mean	**0.2**	**2.2**	**3.6**	**3.1**	**2.0**	**0.7**
SD	**0.5**	**1.4**	**2.1**	**2.2**	**2.1**	**1.2**

Knee Extension Soreness

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	1.0	3.0	2.0	4.0	4.0	1.0
9	1.0	3.0	2.0	3.0	2.0	2.0
11	1.0	1.0	0.0	0.0	1.0	1.0
13	0.0	1.0	2.0	1.0	1.0	1.0
17	4.0	4.0	5.0	5.0	4.0	3.0
20	1.0	3.0	5.0	2.0	1.0	0.0
26	0.0	0.0	4.0	4.0	2.0	0.0
29	0.0	3.0	1.0	1.0	1.0	0.0
32	0.0	2.0	4.0	5.0	2.0	0.0
35	0.0	1.0	1.0	2.0	1.0	1.0
38	0.0	3.0	3.0	0.0	1.0	0.0
41	0.0	1.0	2.0	1.0	0.0	0.0
44	3.0	4.0	5.0	5.0	3.0	3.0
48	0.0	1.0	4.0	2.0	1.0	1.0
49	0.0	3.0	4.0	4.0	4.0	2.0
Mean	**0.7**	**2.2**	**2.9**	**2.6**	**1.9**	**1.0**
SD	**1.2**	**1.3**	**1.6**	**1.8**	**1.3**	**1.1**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	0.0	5.0	6.0	6.0	2.0	1.0
6	0.0	2.0	3.0	3.0	1.0	1.0
8	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	2.0	2.0	2.0	0.0	0.0
14	0.0	2.0	2.0	0.0	1.0	0.0
16	1.0	3.0	4.0	4.0	4.0	2.0
19	1.0	3.0	4.0	2.0	2.0	1.0
25	0.0	1.0	1.0	0.0	0.0	0.0
28	0.0	1.0	1.0	3.0	2.0	0.0
31	1.0	4.0	3.0	3.0	3.0	2.0
34	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	4.0	5.0	2.0	2.0	0.0
43	0.0	3.0	6.0	5.0	3.0	2.0
46	0.0	1.0	0.0	0.0	0.0	0.0
47	0.0	1.0	3.0	2.0	0.0	1.0
Mean	**0.2**	**2.1**	**2.7**	**2.1**	**1.3**	**0.7**
SD	**0.4**	**1.5**	**2.1**	**1.9**	**1.3**	**0.8**

Knee Extension Soreness

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	0.0	1.5	0.0	0.0	0.0	0.0
2	0.0	0.0	3.0	2.0	1.0	0.0
5	0.0	1.0	1.0	4.0	1.0	0.0
7	0.5	3.0	5.0	4.5	4.0	2.5
12	0.0	1.0	2.0	1.0	0.0	0.0
18	0.0	1.0	2.0	2.0	2.0	1.0
21	0.0	0.0	0.0	1.0	0.0	0.0
24	0.0	1.0	0.0	1.0	2.0	1.0
30	0.0	2.0	2.0	2.0	1.0	0.0
33	2.0	7.0	5.0	3.0	1.0	1.0
36	0.0	0.0	0.0	2.0	0.0	0.0
39	0.0	2.0	4.0	2.0	1.0	0.0
42	0.0	1.0	5.0	7.0	3.0	0.0
45	0.0	3.0	3.0	2.0	1.0	0.0
50	0.0	0.0	3.0	2.0	3.0	1.0
Mean	**0.2**	**1.6**	**2.3**	**2.4**	**1.3**	**0.4**
SD	**0.5**	**1.8**	**1.9**	**1.7**	**1.2**	**0.7**

Isometric Knee Extension Strength

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	100.0%	92.4%	104.0%	101.8%	104.0%	106.7%
9	100.0%	87.5%	90.4%	92.9%	88.4%	92.0%
11	100.0%	86.3%	94.6%	94.6%	97.5%	90.3%
13	100.0%	86.3%	94.5%	96.9%	92.9%	96.5%
17	100.0%	82.9%	99.4%	86.2%	108.8%	84.0%
20	100.0%	93.0%	91.3%	99.0%	89.6%	98.3%
26	100.0%	100.9%	95.4%	91.2%	91.2%	102.7%
29	100.0%	94.9%	94.9%	94.6%	95.4%	94.0%
32	100.0%	69.1%	75.2%	82.4%	88.2%	94.2%
35	100.0%	83.8%	79.8%	86.4%	85.1%	90.4%
38	100.0%	102.6%	101.8%	102.6%	92.0%	97.4%
41	100.0%	80.5%	85.1%	99.1%	95.4%	92.4%
44	100.0%	99.6%	103.1%	102.7%	108.5%	111.2%
48	100.0%	80.5%	91.3%	95.7%	97.1%	96.0%
49	100.0%	93.3%	94.8%	101.1%	100.0%	105.6%
Mean	**100.0%**	**88.9%**	**93.0%**	**95.1%**	**95.6%**	**96.8%**
SD	**0.0%**	**9.0%**	**8.1%**	**6.4%**	**7.2%**	**7.2%**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	100.0%	84.3%	89.5%	74.5%	82.4%	88.2%
6	100.0%	75.7%	86.1%	84.8%	89.6%	101.3%
8	100.0%	91.8%	104.1%	92.5%	100.4%	102.2%
10	100.0%	90.7%	96.1%	103.9%	104.3%	103.6%
14	100.0%	93.6%	94.1%	95.0%	90.4%	91.8%
16	100.0%	90.4%	98.4%	97.3%	98.4%	101.6%
19	100.0%	85.4%	89.6%	91.5%	88.9%	85.8%
25	100.0%	95.8%	98.6%	93.5%	85.7%	88.2%
28	100.0%	93.3%	95.8%	99.3%	95.8%	91.9%
31	100.0%	90.8%	90.5%	91.9%	96.0%	91.9%
34	100.0%	91.4%	112.1%	98.0%	93.9%	104.0%
40	100.0%	80.1%	79.7%	91.1%	81.9%	86.1%
43	100.0%	81.1%	76.6%	76.6%	87.1%	94.5%
46	100.0%	87.4%	87.4%	92.0%	95.3%	97.8%
47	100.0%	79.0%	77.7%	94.2%	95.5%	90.3%
Mean	**100.0%**	**87.4%**	**91.7%**	**91.7%**	**92.4%**	**94.6%**
SD	**0.0%**	**6.1%**	**9.8%**	**7.9%**	**6.5%**	**6.6%**

Isometric Knee Extension Strength

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	100.0%	93.1%	96.9%	78.9%	94.7%	94.0%
2	100.0%	85.7%	79.9%	88.1%	84.5%	93.3%
5	100.0%	85.8%	87.1%	90.9%	94.7%	91.5%
7	100.0%	77.3%	78.9%	88.4%	80.2%	95.0%
12	100.0%	89.1%	90.3%	99.1%	91.1%	91.1%
18	100.0%	98.1%	82.7%	92.9%	72.9%	82.0%
21	100.0%	91.2%	84.8%	80.6%	89.1%	96.4%
24	100.0%	84.5%	104.0%	101.1%	90.6%	84.5%
30	100.0%	86.0%	73.7%	82.6%	82.9%	80.1%
33	100.0%	64.2%	72.2%	82.5%	84.6%	79.0%
36	100.0%	79.8%	56.9%	86.7%	71.1%	67.0%
39	100.0%	91.6%	89.4%	97.7%	93.2%	88.6%
42	100.0%	75.2%	90.6%	84.6%	82.3%	81.1%
45	100.0%	101.4%	96.4%	101.1%	101.1%	97.8%
50	100.0%	96.7%	91.4%	99.5%	86.2%	82.9%
Mean	**100.0%**	**86.7%**	**85.0%**	**90.3%**	**86.6%**	**87.0%**
SD	**0.0%**	**9.7%**	**11.7%**	**7.8%**	**8.2%**	**8.4%**

Isometric Elbow Flexion Strength

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	100.0%	76.9%	87.9%	94.5%	98.9%	98.9%
9	100.0%	80.4%	88.2%	92.2%	88.2%	96.1%
11	100.0%	69.4%	67.7%	74.2%	82.3%	91.9%
13	100.0%	70.0%	70.0%	85.0%	93.3%	90.0%
17	100.0%	85.4%	90.2%	102.4%	112.2%	119.5%
20	100.0%	73.8%	72.3%	81.5%	89.2%	87.7%
26	100.0%	86.2%	90.8%	89.7%	85.1%	92.0%
29	100.0%	72.0%	76.0%	78.7%	86.7%	89.3%
32	100.0%	57.8%	70.3%	76.6%	93.8%	98.4%
35	100.0%	81.5%	80.0%	86.2%	90.8%	89.2%
38	100.0%	62.7%	85.1%	76.1%	92.5%	88.1%
41	100.0%	62.2%	55.4%	56.8%	64.9%	77.0%
44	100.0%	92.4%	101.3%	94.9%	107.6%	112.7%
48	100.0%	56.7%	62.5%	68.3%	71.2%	76.0%
49	100.0%	74.4%	75.6%	88.5%	89.7%	94.9%
Mean	**100.0%**	**73.5%**	**78.2%**	**83.0%**	**89.8%**	**93.4%**
SD	**0.0%**	**10.7%**	**12.3%**	**11.7%**	**11.9%**	**11.3%**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	100.0%	87.8%	77.6%	87.8%	77.6%	95.9%
6	100.0%	73.1%	77.6%	73.1%	88.1%	80.6%
8	100.0%	*n.d.*	78.3%	89.1%	93.5%	97.8%
10	100.0%	69.9%	82.2%	91.8%	112.3%	104.1%
14	100.0%	82.4%	88.2%	90.2%	96.1%	102.0%
16	100.0%	83.1%	86.4%	86.4%	86.4%	96.6%
19	100.0%	75.7%	81.1%	85.6%	87.4%	87.4%
25	100.0%	77.8%	70.4%	79.0%	90.1%	91.4%
28	100.0%	66.2%	70.3%	66.2%	77.0%	78.4%
31	100.0%	66.7%	94.7%	98.2%	103.5%	103.5%
34	100.0%	79.2%	79.2%	81.1%	84.9%	90.6%
40	100.0%	90.8%	98.9%	97.7%	103.4%	97.7%
43	100.0%	66.7%	60.3%	76.2%	95.2%	100.0%
46	100.0%	70.2%	73.8%	77.4%	83.3%	92.9%
47	100.0%	84.9%	86.0%	90.3%	93.5%	91.4%
Mean	**100.0%**	**76.7%**	**80.3%**	**84.7%**	**91.5%**	**94.0%**
SD	**0.0%**	**8.2%**	**9.8%**	**9.0%**	**9.8%**	**7.7%**

Isometric Elbow Flexion Strength

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	100.0%	68.4%	60.8%	54.4%	65.8%	68.4%
2	100.0%	74.5%	80.9%	80.9%	85.1%	91.5%
5	100.0%	80.0%	84.0%	82.7%	93.3%	84.0%
7	100.0%	78.3%	80.4%	82.6%	87.0%	91.3%
12	100.0%	69.5%	69.5%	78.0%	75.6%	76.8%
18	100.0%	87.3%	88.6%	93.7%	88.6%	93.7%
21	100.0%	72.1%	67.3%	76.0%	76.9%	82.7%
24	100.0%	67.2%	75.0%	79.7%	76.6%	81.3%
30	100.0%	60.0%	51.3%	77.5%	77.5%	88.8%
33	100.0%	78.8%	67.5%	75.0%	71.3%	75.0%
36	100.0%	77.6%	81.0%	84.5%	84.5%	91.4%
39	100.0%	85.2%	83.3%	87.0%	90.7%	92.6%
42	100.0%	65.3%	71.4%	73.5%	77.6%	79.6%
45	100.0%	75.0%	62.0%	73.1%	85.2%	83.3%
50	100.0%	84.5%	72.4%	91.4%	81.0%	74.1%
Mean	**100.0%**	**74.9%**	**73.0%**	**79.3%**	**81.1%**	**83.6%**
SD	**0.0%**	**7.9%**	**10.3%**	**9.2%**	**7.6%**	**7.8%**

Inertial Load Maximal Cycling Power

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	100.0%	99.0%	101.7%	94.5%	103.3%	104.7%
9	100.0%	104.0%	97.6%	99.2%	96.9%	99.3%
11	100.0%	87.4%	92.8%	91.4%	89.7%	97.6%
13	100.0%	93.5%	100.2%	101.4%	96.7%	94.8%
17	100.0%	100.0%	95.9%	105.1%	111.0%	98.4%
20	100.0%	88.6%	81.9%	79.2%	85.1%	87.1%
26	100.0%	98.0%	101.6%	99.3%	92.5%	85.9%
29	100.0%	94.0%	100.0%	98.5%	104.4%	104.2%
32	100.0%	90.4%	96.8%	89.7%	92.8%	90.9%
35	100.0%	89.8%	98.2%	89.2%	98.2%	93.1%
38	100.0%	93.8%	96.2%	98.5%	101.5%	106.0%
41	100.0%	98.7%	96.6%	100.1%	100.1%	98.9%
44	100.0%	98.1%	95.7%	97.3%	97.1%	92.5%
48	100.0%	90.8%	90.4%	95.4%	97.4%	95.6%
49	100.0%	108.7%	92.6%	89.1%	101.2%	103.4%
Mean	**100.0%**	**95.6%**	**95.9%**	**95.2%**	**97.9%**	**96.8%**
SD	**0.0%**	**6.0%**	**5.0%**	**6.5%**	**6.3%**	**6.2%**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	100.0%	94.4%	96.8%	100.0%	98.4%	97.4%
6	100.0%	86.3%	83.1%	91.9%	91.4%	98.6%
8	100.0%	97.2%	100.7%	100.4%	101.5%	99.9%
10	100.0%	93.4%	98.4%	104.1%	97.5%	98.6%
14	100.0%	101.5%	97.1%	93.2%	96.6%	91.1%
16	100.0%	97.7%	101.9%	98.8%	98.6%	94.6%
19	100.0%	90.9%	98.4%	98.6%	95.5%	101.9%
25	100.0%	88.6%	85.6%	91.9%	91.0%	92.9%
28	100.0%	98.3%	97.9%	101.3%	101.9%	99.6%
31	100.0%	95.0%	94.4%	95.0%	94.3%	90.2%
34	100.0%	95.8%	99.3%	103.1%	100.5%	97.3%
40	100.0%	94.8%	94.8%	105.2%	94.8%	97.0%
43	100.0%	86.7%	67.7%	84.0%	88.7%	87.7%
46	100.0%	89.3%	96.1%	95.7%	92.3%	94.6%
47	100.0%	89.9%	98.4%	98.8%	103.5%	104.7%
Mean	**100.0%**	**93.3%**	**94.0%**	**97.5%**	**96.4%**	**96.4%**
SD	**0.0%**	**4.5%**	**8.9%**	**5.6%**	**4.4%**	**4.6%**

Inertial Load Maximal Cycling Power

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	100.0%	97.5%	95.5%	94.1%	102.5%	99.3%
2	100.0%	90.1%	96.6%	90.8%	95.9%	92.5%
5	100.0%	86.4%	98.1%	94.9%	94.0%	92.2%
7	100.0%	99.2%	93.7%	102.2%	99.6%	102.6%
12	100.0%	90.3%	95.7%	99.4%	98.0%	99.7%
18	100.0%	94.8%	91.0%	91.9%	89.6%	92.7%
21	100.0%	91.4%	91.8%	87.9%	94.3%	101.2%
24	100.0%	95.0%	93.8%	105.3%	90.8%	94.2%
30	100.0%	96.3%	93.8%	98.2%	103.0%	102.9%
33	100.0%	90.0%	87.8%	100.2%	101.3%	89.5%
36	100.0%	90.7%	86.4%	94.0%	97.9%	95.1%
39	100.0%	93.7%	95.0%	96.1%	94.6%	95.1%
42	100.0%	84.5%	98.1%	93.0%	96.3%	95.5%
45	100.0%	96.8%	95.9%	93.4%	93.1%	88.5%
50	100.0%	94.1%	86.3%	89.6%	86.9%	92.3%
Mean	**100.0%**	**92.7%**	**93.3%**	**95.4%**	**95.9%**	**95.6%**
SD	**0.0%**	**4.1%**	**3.9%**	**4.9%**	**4.7%**	**4.6%**

Maximal Instantaneous Power

1x	PRE	24 h	48 h	72 h	96 h
3	100.0%	101.7%	98.3%	104.1%	93.0%
9	100.0%	87.6%	90.9%	93.3%	95.0%
11	100.0%	92.9%	91.8%	90.7%	103.6%
13	100.0%	97.5%	97.6%	94.4%	90.3%
17	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
20	100.0%	88.9%	80.2%	84.8%	94.6%
26	100.0%	106.8%	105.7%	96.0%	95.2%
29	100.0%	94.2%	91.8%	96.2%	98.2%
32	100.0%	94.4%	91.0%	94.8%	89.2%
35	100.0%	103.9%	96.3%	106.2%	105.5%
38	100.0%	106.1%	92.5%	101.6%	97.0%
41	100.0%	102.4%	104.2%	101.0%	109.3%
44	100.0%	94.9%	99.8%	95.8%	92.5%
48	100.0%	91.9%	88.2%	92.6%	90.8%
49	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**97.2%**	**94.5%**	**96.3%**	**96.5%**
SD	**0.0%**	**6.4%**	**6.8%**	**5.8%**	**6.2%**

2x	PRE	24 h	48 h	72 h	96 h
4	100.0%	107.1%	107.6%	103.9%	105.2%
6	100.0%	88.4%	84.5%	99.3%	104.0%
8	100.0%	107.6%	103.5%	105.4%	104.5%
10	100.0%	100.1%	101.4%	94.9%	102.3%
14	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
16	100.0%	102.1%	100.1%	99.4%	91.4%
19	100.0%	102.0%	102.5%	94.6%	104.1%
25	100.0%	92.5%	103.1%	93.7%	98.3%
28	100.0%	99.5%	109.0%	113.2%	113.8%
31	100.0%	95.6%	96.6%	95.6%	90.9%
34	100.0%	97.9%	100.7%	98.7%	95.8%
40	100.0%	85.3%	92.6%	94.6%	89.1%
43	100.0%	66.4%	75.9%	93.7%	90.5%
46	100.0%	99.7%	96.0%	94.5%	93.4%
47	100.0%	105.7%	101.4%	107.0%	106.1%
Mean	**100.0%**	**96.4%**	**98.2%**	**99.2%**	**99.2%**
SD	**0.0%**	**10.8%**	**8.9%**	**6.0%**	**7.5%**

Maximal Instantaneous Power

PLA	PRE	24 h	48 h	72 h	96 h
1	100.0%	98.9%	96.6%	103.7%	104.5%
2	100.0%	102.5%	91.3%	101.6%	95.0%
5	100.0%	97.5%	97.3%	91.6%	93.0%
7	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
12	100.0%	96.4%	98.2%	99.1%	103.1%
18	100.0%	89.4%	89.8%	86.1%	92.6%
21	100.0%	111.1%	95.3%	98.8%	105.4%
24	100.0%	93.1%	98.4%	85.6%	92.9%
30	100.0%	99.9%	106.7%	112.6%	110.5%
33	100.0%	96.9%	103.3%	107.7%	105.9%
36	100.0%	85.9%	95.5%	96.4%	98.1%
39	100.0%	95.4%	94.5%	92.8%	92.6%
42	100.0%	108.7%	103.1%	108.3%	99.6%
45	100.0%	95.3%	95.0%	89.5%	85.2%
50	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**97.8%**	**97.3%**	**98.0%**	**98.3%**
SD	**0.0%**	**6.9%**	**4.8%**	**8.6%**	**7.2%**

Maximal Velocity

1x	PRE	24 h	48 h	72 h	96 h
3	100.0%	100.0%	97.4%	104.4%	112.3%
9	100.0%	119.8%	110.8%	109.9%	105.4%
11	100.0%	92.2%	96.9%	95.3%	93.8%
13	100.0%	109.5%	106.9%	112.9%	100.9%
17	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
20	100.0%	105.2%	111.2%	115.7%	97.8%
26	100.0%	101.7%	97.4%	106.8%	97.4%
29	100.0%	104.9%	104.1%	109.8%	110.6%
32	100.0%	96.8%	96.0%	87.2%	92.0%
35	100.0%	93.8%	95.1%	89.6%	98.6%
38	100.0%	88.2%	109.4%	98.4%	103.9%
41	100.0%	96.5%	102.8%	99.3%	95.1%
44	100.0%	102.9%	104.3%	95.0%	95.0%
48	100.0%	90.9%	97.0%	100.8%	97.0%
49	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**100.2%**	**102.3%**	**101.9%**	**100.0%**
SD	**0.0%**	**8.6%**	**6.0%**	**8.9%**	**6.3%**

2x	PRE	24 h	48 h	72 h	96 h
4	100.0%	91.7%	104.2%	98.3%	98.3%
6	100.0%	86.6%	94.1%	89.9%	91.6%
8	100.0%	95.3%	98.4%	104.7%	103.9%
10	100.0%	102.4%	105.5%	95.3%	97.6%
14	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
16	100.0%	85.6%	84.2%	81.3%	96.4%
19	100.0%	97.1%	99.3%	97.1%	102.9%
25	100.0%	92.9%	95.0%	98.6%	100.7%
28	100.0%	99.2%	94.3%	100.0%	99.2%
31	100.0%	99.2%	99.2%	99.2%	88.2%
34	100.0%	108.0%	106.3%	95.5%	100.9%
40	100.0%	104.3%	108.5%	100.0%	100.9%
43	100.0%	93.2%	100.0%	106.0%	101.7%
46	100.0%	95.6%	96.3%	95.6%	97.8%
47	100.0%	98.3%	98.3%	100.8%	100.0%
Mean	**100.0%**	**96.4%**	**98.8%**	**97.3%**	**98.6%**
SD	**0.0%**	**6.3%**	**6.2%**	**6.1%**	**4.3%**

Maximal Velocity

PLA	PRE	24 h	48 h	72 h	96 h
1	100.0%	96.6%	95.8%	97.5%	97.5%
2	100.0%	96.7%	102.4%	107.3%	111.4%
5	100.0%	106.7%	100.0%	109.0%	99.3%
7	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
12	100.0%	108.2%	104.9%	104.1%	100.8%
18	100.0%	100.0%	106.3%	114.3%	110.7%
21	100.0%	96.1%	112.4%	112.4%	100.8%
24	100.0%	100.9%	107.8%	106.9%	113.8%
30	100.0%	92.9%	89.3%	87.1%	97.9%
33	100.0%	82.0%	95.0%	103.6%	82.7%
36	100.0%	102.3%	103.1%	106.9%	101.5%
39	100.0%	102.3%	97.7%	106.1%	106.9%
42	100.0%	88.0%	86.5%	88.7%	95.5%
45	100.0%	100.7%	97.9%	102.1%	103.4%
50	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**98.0%**	**99.9%**	**103.5%**	**101.7%**
SD	**0.0%**	**7.2%**	**7.3%**	**8.1%**	**8.1%**

Maximal Torque

1x	PRE	24 h	48 h	72 h	96 h
3	100.0%	101.3%	97.5%	98.7%	92.4%
9	100.0%	76.8%	83.8%	82.8%	88.9%
11	100.0%	101.4%	94.2%	94.2%	104.3%
13	100.0%	92.0%	96.0%	85.3%	94.7%
17	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
20	100.0%	82.2%	74.0%	76.7%	93.2%
26	100.0%	101.0%	102.0%	87.9%	98.0%
29	100.0%	96.4%	96.4%	95.2%	95.2%
32	100.0%	98.8%	90.4%	103.6%	97.6%
35	100.0%	104.6%	93.8%	109.2%	93.8%
38	100.0%	117.9%	91.0%	103.0%	103.0%
41	100.0%	101.2%	98.8%	102.4%	105.9%
44	100.0%	93.5%	93.5%	103.3%	96.7%
48	100.0%	98.7%	98.7%	97.5%	97.5%
49	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**97.4%**	**93.1%**	**95.4%**	**97.0%**
SD	**0.0%**	**10.2%**	**7.3%**	**9.6%**	**4.9%**

2x	PRE	24 h	48 h	72 h	96 h
4	100.0%	105.9%	96.1%	99.0%	99.0%
6	100.0%	96.3%	87.5%	102.5%	107.5%
8	100.0%	104.2%	100.0%	97.2%	95.8%
10	100.0%	96.2%	98.7%	103.8%	103.8%
14	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
16	100.0%	119.6%	115.7%	121.6%	98.0%
19	100.0%	101.1%	100.0%	101.1%	98.9%
25	100.0%	92.9%	98.0%	92.9%	93.9%
28	100.0%	98.7%	107.7%	101.3%	100.0%
31	100.0%	96.1%	96.1%	94.7%	102.6%
34	100.0%	92.4%	94.9%	105.1%	94.9%
40	100.0%	90.1%	97.5%	93.8%	95.1%
43	100.0%	71.9%	82.0%	82.0%	86.5%
46	100.0%	99.0%	99.0%	96.0%	97.0%
47	100.0%	100.0%	99.1%	101.9%	102.8%
Mean	**100.0%**	**97.5%**	**98.0%**	**99.5%**	**98.3%**
SD	**0.0%**	**10.3%**	**7.8%**	**8.7%**	**5.2%**

Maximal Torque

PLA	PRE	24 h	48 h	72 h	96 h
1	100.0%	98.9%	97.8%	101.1%	102.2%
2	100.0%	98.6%	87.1%	88.6%	82.9%
5	100.0%	92.6%	94.9%	86.0%	93.4%
7	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
12	100.0%	88.6%	94.3%	93.2%	98.9%
18	100.0%	89.8%	86.4%	77.3%	84.1%
21	100.0%	95.6%	78.0%	83.5%	101.1%
24	100.0%	92.4%	96.2%	83.5%	81.0%
30	100.0%	100.0%	107.5%	115.1%	103.2%
33	100.0%	105.7%	104.3%	97.1%	108.6%
36	100.0%	84.2%	90.8%	92.1%	94.7%
39	100.0%	96.3%	97.5%	88.9%	88.9%
42	100.0%	112.1%	109.1%	109.1%	103.0%
45	100.0%	94.6%	96.8%	90.3%	86.0%
50	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**96.1%**	**95.4%**	**92.8%**	**94.5%**
SD	**0.0%**	**7.3%**	**8.7%**	**10.6%**	**9.1%**

Torque at 0°

1x	PRE	24 h	48 h	72 h	96 h
3	100.0%	73.9%	83.0%	100.7%	71.2%
9	100.0%	208.8%	166.2%	230.9%	247.1%
11	100.0%	86.0%	92.6%	86.8%	90.4%
13	100.0%	101.8%	121.1%	94.7%	110.5%
17	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
20	100.0%	94.4%	95.4%	114.8%	116.7%
26	100.0%	101.7%	74.4%	92.2%	79.4%
29	100.0%	101.3%	82.6%	101.9%	92.3%
32	100.0%	135.8%	151.6%	165.3%	160.0%
35	100.0%	112.5%	108.7%	115.4%	110.6%
38	100.0%	148.3%	94.8%	81.9%	78.4%
41	100.0%	192.1%	180.3%	198.7%	142.1%
44	100.0%	115.6%	122.5%	116.3%	113.1%
48	100.0%	133.3%	137.7%	133.3%	143.0%
49	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**123.5%**	**116.2%**	**125.6%**	**119.6%**
SD	**0.0%**	**40.0%**	**34.0%**	**45.7%**	**46.9%**

2x	PRE	24 h	48 h	72 h	96 h
4	100.0%	84.0%	62.9%	99.1%	92.5%
6	100.0%	95.9%	100.7%	89.0%	115.9%
8	100.0%	96.0%	98.0%	98.0%	97.3%
10	100.0%	100.0%	103.4%	109.6%	97.9%
14	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
16	100.0%	86.5%	82.7%	91.3%	80.8%
19	100.0%	93.4%	98.9%	82.5%	86.3%
25	100.0%	109.0%	94.9%	91.7%	115.4%
28	100.0%	98.7%	102.6%	103.3%	86.3%
31	100.0%	90.5%	108.0%	94.2%	75.9%
34	100.0%	149.4%	113.8%	134.5%	173.6%
40	100.0%	126.7%	132.2%	145.6%	144.4%
43	100.0%	104.2%	147.9%	129.2%	106.3%
46	100.0%	84.1%	61.0%	74.9%	92.3%
47	100.0%	66.3%	55.8%	109.0%	58.3%
Mean	**100.0%**	**98.9%**	**97.3%**	**103.7%**	**101.7%**
SD	**0.0%**	**20.0%**	**25.9%**	**20.3%**	**29.2%**

Torque at 0°

PLA	PRE	24 h	48 h	72 h	96 h
1	100.0%	100.0%	102.2%	98.3%	56.4%
2	100.0%	91.7%	87.1%	91.7%	90.9%
5	100.0%	88.1%	106.7%	88.1%	102.8%
7	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
12	100.0%	90.1%	88.5%	97.4%	106.3%
18	100.0%	65.2%	85.2%	81.3%	84.5%
21	100.0%	100.0%	120.0%	91.8%	153.6%
24	100.0%	150.0%	158.5%	140.4%	98.9%
30	100.0%	117.6%	83.0%	113.1%	135.3%
33	100.0%	72.0%	70.2%	63.7%	75.0%
36	100.0%	91.3%	101.6%	102.4%	96.8%
39	100.0%	95.2%	67.3%	80.3%	98.0%
42	100.0%	99.2%	101.5%	97.0%	100.8%
45	100.0%	157.8%	181.9%	168.7%	138.6%
50	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**101.4%**	**104.1%**	**101.1%**	**102.9%**
SD	**0.0%**	**26.7%**	**33.1%**	**27.2%**	**26.5%**

Vertical Jump Height

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	100.0%	94.7%	100.0%	92.1%	97.4%	102.6%
9	100.0%	97.1%	94.3%	97.1%	94.3%	97.1%
11	100.0%	97.6%	100.0%	102.4%	104.9%	107.3%
13	100.0%	96.7%	96.7%	100.0%	96.7%	100.0%
17	100.0%	100.0%	93.9%	103.0%	103.0%	103.0%
20	100.0%	97.3%	102.7%	102.7%	102.7%	100.0%
26	100.0%	97.7%	97.7%	102.3%	104.5%	100.0%
29	100.0%	102.5%	102.5%	102.5%	107.5%	107.5%
32	100.0%	94.1%	97.1%	97.1%	100.0%	94.1%
35	100.0%	95.1%	92.7%	92.7%	104.9%	95.1%
38	100.0%	102.9%	100.0%	108.6%	108.6%	108.6%
41	100.0%	100.0%	101.7%	103.4%	103.4%	105.2%
44	100.0%	97.6%	100.0%	97.6%	95.1%	100.0%
48	100.0%	89.7%	94.9%	94.9%	97.4%	100.0%
49	100.0%	102.8%	100.0%	100.0%	105.6%	108.3%
Mean	**100.0%**	**97.7%**	**98.3%**	**99.8%**	**101.7%**	**101.9%**
SD	**0.0%**	**3.6%**	**3.2%**	**4.5%**	**4.6%**	**4.7%**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	100.0%	93.9%	87.9%	100.0%	97.0%	97.0%
6	100.0%	97.4%	102.6%	102.6%	117.9%	105.1%
8	100.0%	97.0%	90.9%	93.9%	93.9%	97.0%
10	100.0%	95.3%	100.0%	100.0%	95.3%	104.7%
14	100.0%	92.1%	100.0%	97.4%	105.3%	102.6%
16	100.0%	94.4%	94.4%	91.7%	86.1%	91.7%
19	100.0%	95.8%	97.9%	102.1%	102.1%	102.1%
25	100.0%	98.1%	98.1%	100.0%	103.8%	103.8%
28	100.0%	100.0%	96.7%	100.0%	100.0%	103.3%
31	100.0%	94.3%	94.3%	94.3%	100.0%	97.1%
34	100.0%	96.7%	96.7%	100.0%	96.7%	106.7%
40	100.0%	100.0%	102.3%	106.8%	109.1%	102.3%
43	100.0%	97.1%	102.9%	97.1%	102.9%	102.9%
46	100.0%	91.9%	102.7%	105.4%	110.8%	110.8%
47	100.0%	100.0%	100.0%	102.6%	105.3%	102.6%
Mean	**100.0%**	**96.3%**	**97.8%**	**99.6%**	**101.7%**	**102.0%**
SD	**0.0%**	**2.6%**	**4.5%**	**4.2%**	**7.7%**	**4.7%**

Vertical Jump Height

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	100.0%	97.4%	100.0%	94.9%	97.4%	100.0%
2	100.0%	93.0%	90.7%	93.0%	93.0%	93.0%
5	100.0%	91.1%	97.8%	95.6%	100.0%	93.3%
7	100.0%	100.0%	106.9%	106.9%	106.9%	106.9%
12	100.0%	100.0%	97.1%	100.0%	100.0%	100.0%
18	100.0%	100.0%	102.7%	100.0%	100.0%	100.0%
21	100.0%	100.0%	98.0%	100.0%	102.0%	106.1%
24	100.0%	97.6%	97.6%	95.1%	92.7%	95.1%
30	100.0%	100.0%	102.0%	104.1%	104.1%	104.1%
33	100.0%	103.2%	100.0%	96.8%	100.0%	96.8%
36	100.0%	90.2%	95.1%	95.1%	97.6%	97.6%
39	100.0%	95.8%	100.0%	100.0%	100.0%	100.0%
42	100.0%	93.8%	90.6%	90.6%	96.9%	100.0%
45	100.0%	100.0%	96.1%	96.1%	100.0%	98.0%
50	100.0%	97.9%	91.7%	95.8%	91.7%	87.5%
Mean	**100.0%**	**97.3%**	**97.7%**	**97.6%**	**98.8%**	**98.6%**
SD	**0.0%**	**3.8%**	**4.5%**	**4.2%**	**4.2%**	**5.1%**

10-Meter Sprint Velocity

1x	PRE	2 h	24 h	48 h	72 h	96 h
3	100.0%	99.1%	98.7%	95.3%	98.7%	97.8%
9	100.0%	98.9%	101.7%	98.9%	98.9%	101.7%
11	100.0%	99.4%	93.3%	102.9%	105.9%	104.0%
13	100.0%	102.2%	96.9%	102.2%	100.0%	102.2%
17	100.0%	97.2%	97.2%	96.1%	98.3%	95.6%
20	100.0%	98.9%	95.0%	97.2%	96.1%	95.0%
26	100.0%	100.0%	97.6%	98.8%	100.0%	97.6%
29	100.0%	98.8%	100.0%	98.2%	98.8%	98.8%
32	100.0%	98.3%	96.6%	98.9%	98.9%	*n.d.*
35	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
38	100.0%	102.4%	100.0%	103.7%	105.6%	104.3%
41	100.0%	101.9%	100.6%	100.0%	99.4%	101.9%
44	100.0%	101.8%	99.4%	101.8%	104.4%	105.7%
48	100.0%	96.0%	93.9%	93.9%	98.3%	97.7%
49	100.0%	112.7%	104.3%	104.3%	107.1%	110.8%
Mean	**100.0%**	**100.6%**	**98.2%**	**99.4%**	**100.7%**	**101.0%**
SD	**0.0%**	**4.0%**	**3.1%**	**3.2%**	**3.5%**	**4.5%**

2x	PRE	2 h	24 h	48 h	72 h	96 h
4	100.0%	94.4%	96.4%	97.9%	97.9%	98.4%
6	100.0%	96.7%	100.0%	107.9%	104.7%	104.1%
8	100.0%	96.1%	99.4%	95.1%	101.2%	101.8%
10	100.0%	98.9%	103.6%	102.4%	101.2%	99.4%
14	100.0%	98.4%	95.8%	97.9%	97.9%	98.4%
16	100.0%	83.0%	103.9%	102.8%	101.1%	100.5%
19	100.0%	95.7%	95.1%	94.5%	95.7%	94.5%
25	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
28	100.0%	98.9%	99.4%	96.8%	97.8%	98.9%
31	100.0%	101.7%	96.3%	101.1%	103.4%	101.1%
34	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
40	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
43	100.0%	98.4%	95.4%	98.9%	99.5%	105.1%
46	100.0%	99.4%	98.3%	98.8%	98.3%	100.0%
47	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
Mean	**100.0%**	**96.5%**	**98.5%**	**99.5%**	**99.9%**	**100.2%**
SD	**0.0%**	**4.9%**	**3.1%**	**3.9%**	**2.7%**	**2.9%**

10-Meter Sprint Velocity

PLA	PRE	2 h	24 h	48 h	72 h	96 h
1	100.0%	95.6%	96.9%	90.5%	95.2%	94.4%
2	100.0%	83.0%	99.0%	97.6%	100.5%	100.0%
5	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
7	100.0%	100.0%	97.9%	97.4%	95.8%	99.5%
12	100.0%	96.1%	99.4%	103.0%	100.0%	106.1%
18	100.0%	99.4%	98.4%	100.0%	102.3%	104.7%
21	100.0%	95.9%	96.4%	92.1%	96.4%	97.6%
24	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
30	100.0%	103.2%	98.8%	101.9%	99.4%	100.6%
33	100.0%	99.4%	97.2%	96.6%	99.4%	96.1%
36	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*	*n.d.*
39	100.0%	94.4%	96.6%	97.7%	98.8%	97.7%
42	100.0%	94.5%	91.4%	92.4%	92.4%	93.4%
45	100.0%	95.9%	99.4%	101.9%	101.9%	100.6%
50	100.0%	98.8%	95.5%	96.1%	103.0%	101.8%
Mean	**100.0%**	**96.4%**	**97.2%**	**97.3%**	**98.8%**	**99.4%**
SD	**0.0%**	**5.0%**	**2.2%**	**4.1%**	**3.2%**	**3.8%**

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